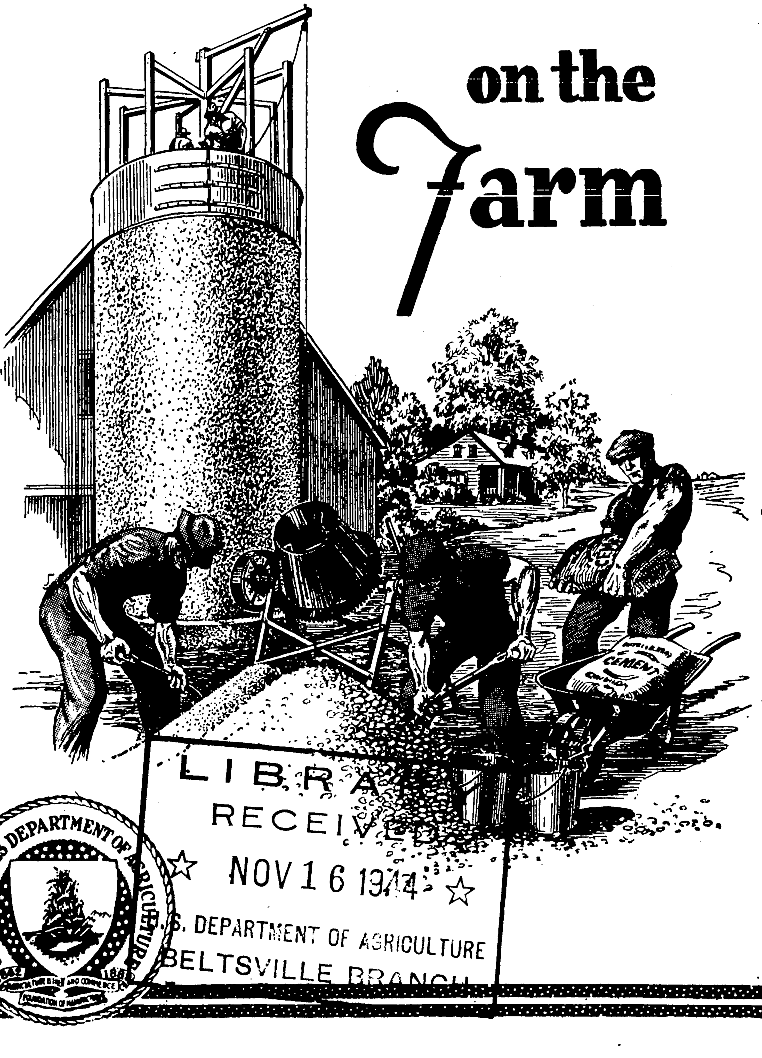
# U. S. DEPARTMENT OF AGRICULTURE

FARMERS' BULLETIN No. 1772

# Use of Concrete on the Farm



THE successful and economical use of concrete involves the selection of suitable materials, the correct proportioning of mixtures for developing the qualities to meet specific requirements, and the proper placing and care of the green concrete. Little is gained by adding various ingredients to get special qualities in concrete. A well-made concrete, a suitable mixture for the work at hand and properly cured, will provide the qualities desired.

The quantity of water used per bag of cement is more important than is generally realized by those unfamiliar with concrete, when strength or watertightness is the objective. However, a concrete of great strength is uneconomical if a weaker mixture will serve, and a cheap or weak concrete is costly if it does not fulfill all requirements. Lack of foresight in locating the mixing plant, in designing the forms, and in planning the successive operations may cause unnecessary expense, while neglect of any one of the precautions that should be observed is likely to result in unsatisfactory work.

This bulletin discusses the requirements of good concrete for different purposes and describes methods of building some simple concrete structures useful on the farm. It supersedes Farmers' Bulletins 1279, Plain Concrete for Farm Use; and 1480, Small Concrete Construction on the Farm.

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# USE OF CONCRETE ON THE FARM

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## INTRODUCTION

PORTLAND CEMENT, sand, gravel (or other coarse aggregate), and water all go into making portland cement concrete. This material may be made to conform to certain requirements, which vary with the purpose of the structure in which it is to be used. The chief requisite may be economy, strength, watertightness, light weight, or resistance to wear and shock. Important in securing the desired end are such factors as the substances entering into its composition, the proportions in which they are used, the consistency of the mixture, the method of mixing, and the way in which the concrete is placed and cured.

[1] The author is indebted to W. C. Harrington, extension agricultural engineer, Massachusetts State College, to H. F. McColly, agricultural engineer, North Dakota Agricultural College, and to other agricultural engineers for assistance in the preparation of this bulletin.

Often concrete fails to give the service expected because procedures recognized as essential in its preparation have been neglected. Intended as a guide in making and manipulating concrete suitable for general farm use, this bulletin discusses only plain concrete, incidental reinforcement, and methods of constructing farm equipment and small concrete structures.

## MATERIALS

### CEMENT

Portland cement is used extensively in general construction work. There are three kinds in common use: (1) The ordinary gray cement, employed for general concrete work; (2) white cement, used for white stuccos and ornamental art concretes; and (3) early-high-strength cement, especially useful under special conditions on account of its quick-setting property. The white and early-high-strength cements cost more than the ordinary gray kind. There are other cements than portland, but their individual characteristics restrict their use. The word "portland" is not a trade name but is used to distinguish this type of cement from slag, natural, and other cements.

A number of brands of portland cement are manufactured, practically all of which are made to meet the requirements of a fixed standard adopted by the United States Government and the American Society for Testing Materials. Cement should always be tested before being used in important work, but such tests are impractical for the user of small amounts, and it is generally safe to omit the test if a reliable brand of portland cement of American manufacture is selected, especially if the dealer's or manufacturer's guaranty that it meets the standard is obtained.

Portland cement is commonly shipped in paper bags or cloth sacks. For the average user the paper bag or sack is the best container. A sack of portland cement weighs 94 pounds and a barrel contains 376 pounds, the equivalent of four sacks.

#### STORING CEMENT

As cement readily absorbs moisture from the atmosphere, it should be stored in a dry place; if exposed to dampness it soon becomes lumpy, or even a solid mass, and in this condition it is useless and should be thrown away. Paper bags protect the cement from moisture better than do cloth sacks. The lumps caused by pressure in piling the sacks are not injurious. These can be pulverized easily and can thus be distinguished from lumps due to dampness. Sometimes cement that has become lumpy from dampness is sifted to reclaim the powder. Before using salvaged cement, samples of concrete should be made to make certain that it is fit to use.

Cement should never be stored on the ground. Build a raised platform for it and keep it away from the sides of the shelter. As it is heavy, care should be taken not to overload the supporting floor.

### FINE AGGREGATE (SAND)

All grains, small pebbles, or particles of broken stone, brick, tile, etc., are considered to be sand if they will pass through a wire screen with 1/4-inch meshes. The particles or grains should be hard and

well graded and should vary in size from fine (excluding dust) to coarse (fig. 1), as a stronger concrete is thus obtained than when the size of the grains is nearly uniform (fig. 2). More cement is required when the sand is fine.

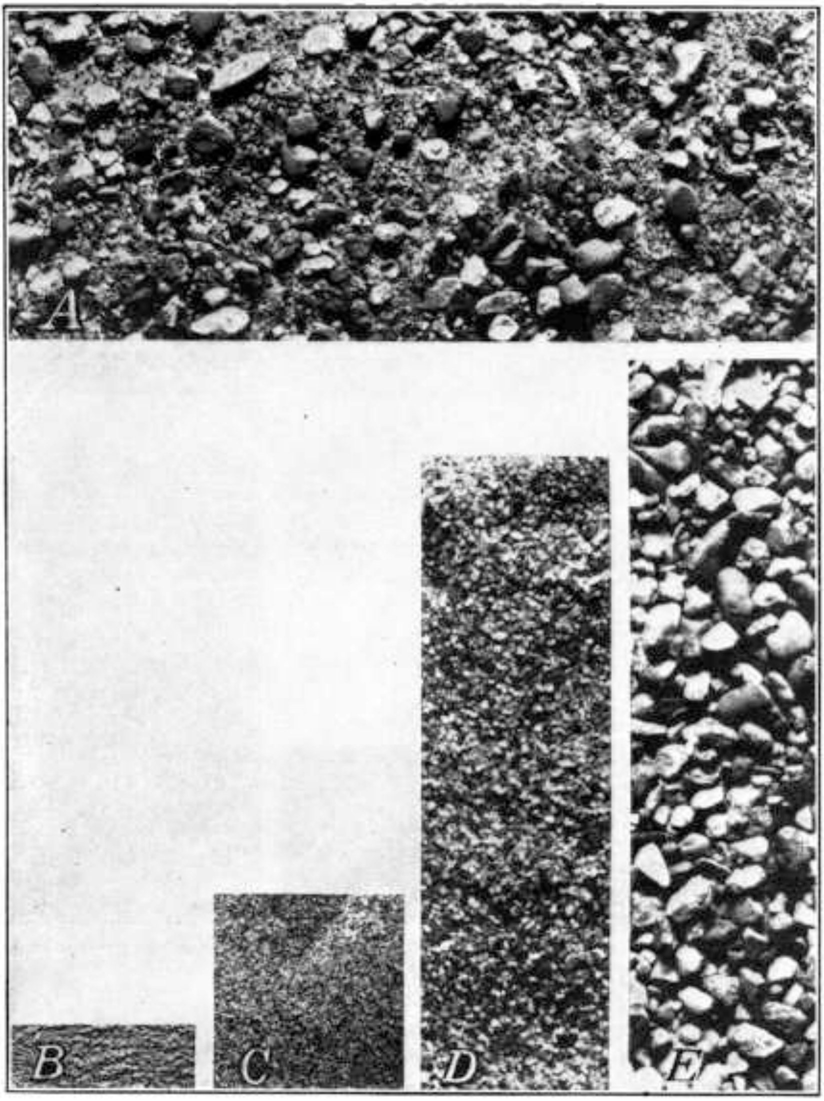


FIGURE 1.—*A*, Sample of good concrete sand before separation into various sizes; *B*, passing no. 100 screen; *C*, passing no. 48 but retained on no. 100 screen; *D*, passing no. 14 but retained on no. 48 screen; *E*, passing no. 4 but retained on no. 14 screen. Height of strip indicates amount of that size.

Sand from salt-water beaches should not be used without thorough washing to remove the salt and other impurities. As it is rather difficult to do this, using sand from other sources is often more economical.

All sand should be clean; that is, free from vegetable matter, loam, or any considerable amount of clay. If the hands are soiled when a small quantity of sand is rubbed between them, the following test for silt should be made: Put 2 inches of the sand into an ordinary 1-quart fruit jar, add water until the jar is about three-fourths full, screw on the cover, shake the jar vigorously until the sand is thoroughly washed, and allow the contents to settle. Any silt present will be deposited in a layer above the sand. If the layer of silt,

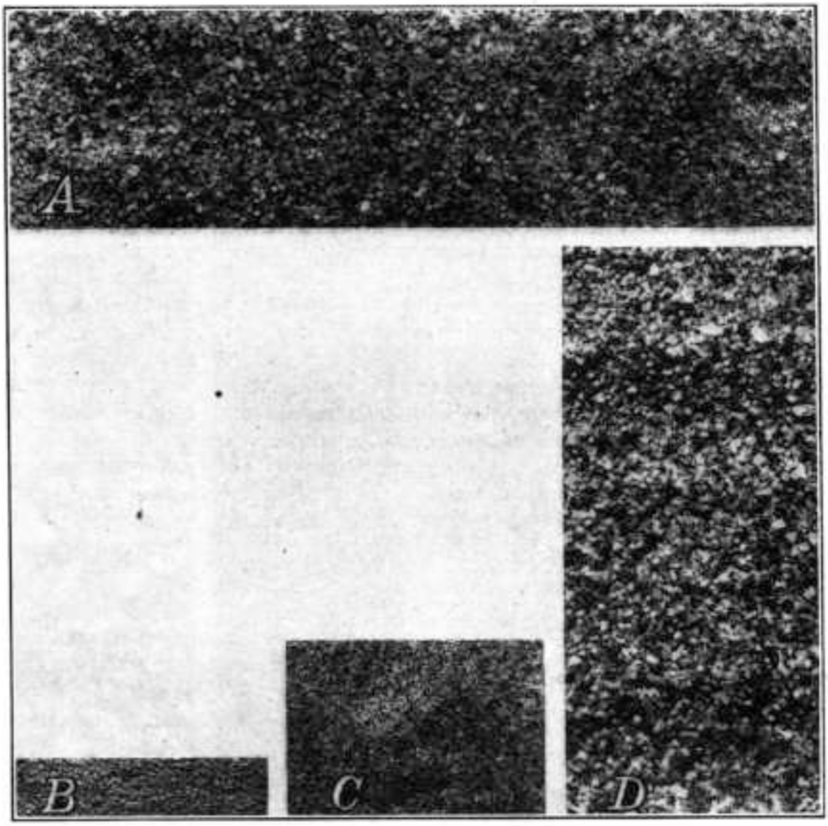


FIGURE 2.—*A*, Sample of poor concrete sand, lacking large particles; *B*, portion passing no. 100 screen; *C*, passing no. 48 but retained on no. 100 screen; *D*, passing no. 14 but retained on no. 48 screen.

after settling for 24 hours, is more than one-eighth of an inch thick, the sand is unsuitable for concrete unless the silt is removed by washing.

###### WASHING SAND

The simplest way to wash small quantities of sand is to build a loose board platform from 10 to 12 feet long, with one end 3 or 4 feet higher than the other. On the lower end and sides nail 1- by 6-inch boards, and on the bottom nail 1- by 2-inch cleats 18 inches apart. Spread the sand over the platform in a layer 3 or 4 inches thick, and wash with water applied by any means that will agitate

the sand and allow the lighter material to run off with the water; a garden hose is very convenient. The washing should be started at the higher end and the water allowed to run through the sand.

### ORGANIC IMPURITIES

Sand may contain decaying humus, which often forms tannic acid that will weaken concrete. The presence of harmful amounts of organic matter in sand can be detected by a simple test, except in areas where there are deposits of lignite. Lignite or coal may give the liquid a very dark color, though the quantities may not be sufficient to reduce the strength of concrete appreciably and the sand may be otherwise acceptable. In such cases a laboratory test should be made to determine the exact effect of such impurities.

In making this test, a heaping teaspoonful of lye is dissolved thoroughly in a half pint of clear water. Any household lye is suitable that consists of at least 94 percent of sodium hydroxide. Pour this solution into a glass jar containing one-half pint of the sand to be tested. Place the cover on the jar and shake vigorously for a minute or so, then set the jar aside to settle. After several hours the color of the liquid will indicate whether the sand contains injurious amounts of organic matter. A clear liquid indicates a clean sand. A straw-colored liquid indicates some organic matter, but not enough to be seriously objectionable. Colors as dark or darker than coffee show excessive amounts of organic matter, in which case the sand should not be used unless washed and a retest shows that it is then satisfactory. Reasonable care must be used in measuring all materials, as variations in concentration of the solution may alter the color. This solution is highly injurious to clothing, the skin, and other materials and should not be spilled. Glass utensils only should be used for tests.

This test is very valuable in localities where trouble has been experienced in getting concrete to harden properly.

Loose vegetable matter can be floated out or washed out like silt.

### COARSE AGGREGATE

The larger particles used in concrete are referred to as coarse aggregate, and should range in size from one-fourth inch up to 1½ or 2 inches (fig. 3). The maximum size to be used is governed by the nature of the work. Ordinarily the greatest dimension of any particle should not be more than one-third the thickness of the wall or slab in which it is to be used.

Various inert materials are used for coarse aggregate, depending upon their availability or upon special properties to be developed in the concrete. For general purposes, gravel, crushed stone, and air-cooled blast-furnace slag are suitable. The particles should be tough, fairly hard, and free from any of the impurities that would be objectionable in sand. A considerable portion of soft, flat, or elongated particles should be avoided.

### GRAVEL

The word "gravel", as used in this bulletin, designates pebbles, and should not be confused with the term "bank-run gravel", which is

used to designate a natural mixture of sand and pebbles. Gravel that is too dirty for use usually can be detected by observation. Lumps of clay should be eliminated, and care should be taken to see that the gravel is not coated with film of clay or loam which will prevent bonding with the cement. In making concrete it is necessary to add sand to screened gravel, but not to unscreened bank-run

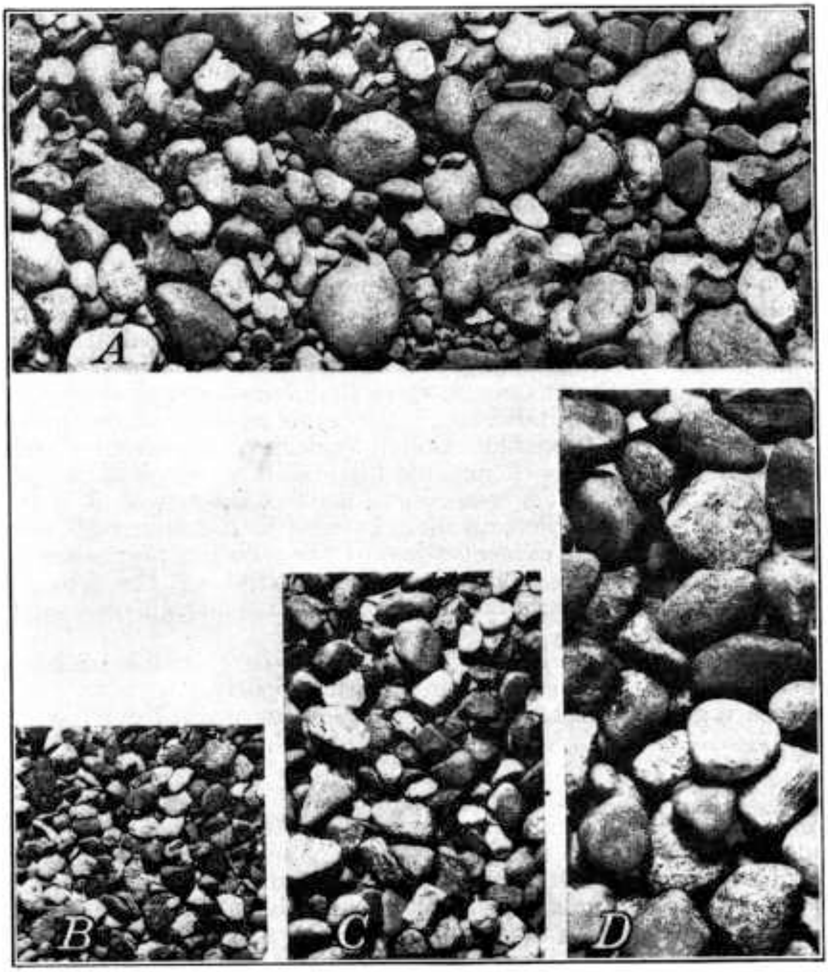


FIGURE 3.—*A*, Sample of well-graded gravel; *B*, portion passing ⅜-inch but retained on no. 4 screen; *C*, passing ¾-inch but retained on ⅜-inch screen; *D*, passing 1½ inch but retained on ¾-inch screen. Note how the small particles fit between the large particles in the mixed gravel.

gravel, as the latter generally contains too much sand when excavated.

Where stone is obtainable at low cost, about one-half to two-thirds the amount of concrete required for foundations and walls having a large cross section can be saved by substituting stone about the size of a man's head. The stones should be clean and sound and embedded in the concrete so as not to show on the finished wall surfaces.

### BANK RUN GRAVEL

Bank or creek gravel that will answer the purpose of sand and gravel combined sometimes can be obtained, and frequently it is used in small jobs of concrete work just as it comes from the pit or creek. Although such gravel occasionally contains nearly the right proportions of sand and gravel, in the majority of sand pits and gravel banks there is a great variation in the sizes of the particles and in the relative quantity of each. A test to determine whether bank run contains approximately the right balance of sand and gravel is made by selecting from the pit a representative sample of at least 2 cubic feet and screening it over a ¼-inch mesh screen. The part passing through the screen is considered sand, while the part retained is gravel. In a well-graded mixture the proportions of fine and coarse aggregate should be approximately those stated on page 11. Unless the sand and gravel exist in approximately the correct proportions, they should be separated by screening and remixed in the correct proportions, as well-graded aggregates make stronger concrete, and, ordinarily, enough cement will be saved to pay for the cost of screening.

### WASHING GRAVEL

Generally gravel cannot be washed thoroughly by pouring water over a pile unless there is only a small quantity on a platform, where it can be stirred by shoveling and the dirty water allowed to drain away freely. A large supply of water must also be available. While it is feasible to wash small quantities on a loose-bottom wagon, as generally done such washing is likely to be ineffective. A concrete mixer can sometimes be utilized for washing by putting a quantity of gravel and an abundance of water into it and revolving it several times. Generally one such washing will clean the gravel. When a considerable quantity of gravel or bank run must be washed, especially if poorly graded as to size, it may be more economical to purchase clean, well-graded material from commercial sources.

### BROKEN STONE

Broken stone should be clean, hard, and of a size suited to the character of the work, and the same care in grading should be exercised as in the case of gravel. Trap, granite, hard limestone, and hard sandstone are commonly used.

Field stones are common in many localities, and it may be economical to use them after they have been crushed. Small stone crushers operated by gasoline engines of three or four horsepower may be profitable if a large amount of stone is needed. The finer particles, after the dust is removed, can be used as sand. Broken terra cotta, brick, and old concrete, if hard and strong, may be used for unimportant work where no great strength is required, as in the base course of pavements and in walls of lightweight buildings, but special care should be taken not to have the particles show on the finished surface.

### LIGHTWEIGHT AGGREGATES

The ordinary weight of concrete is about 145 pounds per cubic foot. Lighter weight concrete suitable for certain purposes may be made

by using aggregates of light weight. For years cinders have been used, from which concrete weighing 120 pounds per cubic foot can be made. Recently burnt clay manufactured by a special process has come into use, with which a concrete weighing 100 pounds can be made. Processed water-cooled blast-furnace slag also is available, and when used makes a concrete weighing 130 pounds. By using patented processes concrete can be obtained that weighs as little as 50 pounds per cubic foot.

Concrete made from these materials is fire resistant and has certain insulating qualities, but must not be employed for watertight structures or where it will be subjected to abrasion or heavy loads. Lightweight concrete is especially useful for filling between floor sleepers, for making precast blocks and roof slabs, and for fireproofing, but when structural strength is required it should be used only by experienced builders. Information regarding the availability and methods of using the patented lightweight aggregates is best obtained from local dealers. Such materials cannot be had in all localities, but are becoming more generally available than formerly.

If cinders are to be used in concrete, they should be composed of hard, clean, vitreous clinkers free from sulphides, soot, and unburned coal or ashes. As a precaution against the presence of small amounts of detrimental substances, cinders should be soaked thoroughly in water 24 hours before being used. If clean, they will not discolor the hands when a small quantity is rubbed between the palms. Ashes from cook stoves and similar domestic heaters are not at all suitable for aggregate and must not be confused with cinders. Lignite ashes contain a considerable amount of alkali, which disintegrates concrete.

Lava rock varies widely in chemical composition and physical qualities. In some instances lavas are so light and frothy or contain so large a portion of easily oxidizable material that they are wholly unsuited for concrete work. The lava rock found in the Northwestern States is generally a suitable substitute for gravel. Rhyolite, which is a light-colored volcanic rock, and many of the darker basaltic lavas are suitable for concrete for buildings.

## WATER

Water should be clean and free from strong acid, oil, alkali, and organic matter. Sea or brackish water should not be used because of the danger of corroding reinforcement and of reducing the strength of the concrete. Alkali salts are destructive if in excess of 0.5 percent. In general, any water that is drinkable is satisfactory.

## CONSISTENCY

The quantity of water used in mixing has a great influence on the strength of concrete.

The cement and water when mixed form a paste which on hardening binds the sand and gravel into a solid mass. Too much water dilutes this paste and thus weakens its cementing properties. The strength of concrete at a given age depends upon the proportion of cement to water, regardless of the quantities of aggregate, so long as the mixture is plastic and workable. However, it must be understood that a lean mixture (one containing a relatively large quantity

of aggregate) will not make as strong concrete as a richer mixture because more water per bag of cement must be used to give the desired workability. A workable mixture is one which is of such a wetness that it can be placed readily in the forms and which with spading or tamping will result in a dense concrete (fig. 4).

The same degree of stiffness or workability is not required for all classes of work. For thin sections or where reinforcement is closely spaced, the concrete should be plastic enough to flow readily. However, very wet or sloppy mixtures should not be used, as the gravel will segregate and cause porous concrete. For general work a concrete between the flowing and dry mixtures is recommended.

For precast blocks and other cement products from which the forms are to be removed in a short time, the concrete must necessarily be mixed fairly dry, as otherwise it will stick to the forms. The workable consistency is about that of damp earth, so that if a handful is squeezed it will retain its shape. Such stiffness requires thorough ramming to reduce voids and should not be used where watertightness is required. Dry-mixed concrete products require better than average curing and, whenever possible, should be kept thoroughly wet for at least a week after making.

A very rough estimate of the quantity of water required in mixing is 5 to 6 gallons to each sack of cement. The quantity will vary, depending upon the proportions and grading as well as upon the amount of moisture in the sand and gravel. When a ½-sack batch of concrete is to be mixed, obviously only 2½ to 3 gallons of water will be required. The amounts to use for various kinds of work are suggested in table 1. The amount of water to use for other mixtures can be computed from the figures given in the table.

TABLE 1.—*Concrete mixtures recommended for various kinds of work*

| Kind of work | Proportions | | | Water required per sack of cement with aggregates— | | |
|---|---|---|---|---|---|---|
| | Cement | Sand | Gravel | Wet | Moist | Dry |
| | *Sacks* | *Cubic feet* | *Cubic feet* | *Gallons* | *Gallons* | *Gallons* |
| Very thin sections—<br>2 to 4 inches thick (fence posts, garden furniture, milk-cooling tanks) | 1 | 2 | 2 | 3½ | 3¾ | 4½ |
| Exceptional watertightness and resistance to abrasion—sections 4 to 8 inches thick (tanks corner posts, silos) | 1 | 2 | 3 | 3¾ | 4½ | 5½ |
| General reinforced and watertight work—sections 8 to 12 inches thick (basement walls, pavements, steps) | 1 | 2½ | 3½ | 4½ | 5 | 6½ |
| Mass concrete of moderate strength not watertight (footings, foundation walls) | 1 | 3 | 5 | 5 | 6 | 7 |

If the mixtures recommended in this table produce a concrete that is too stiff, too sloppy, or too harsh, the quantity of sand and gravel should be reduced or increased so as to secure the proper degree of wetness for the kind of work being done. Under no circumstances should the quantity of water specified per sack of cement be changed. There must be just enough cement-sand mortar to fill the spaces between the gravel and assure a smooth plastic mixture. Greatest economy can be secured by using aggregate containing particles

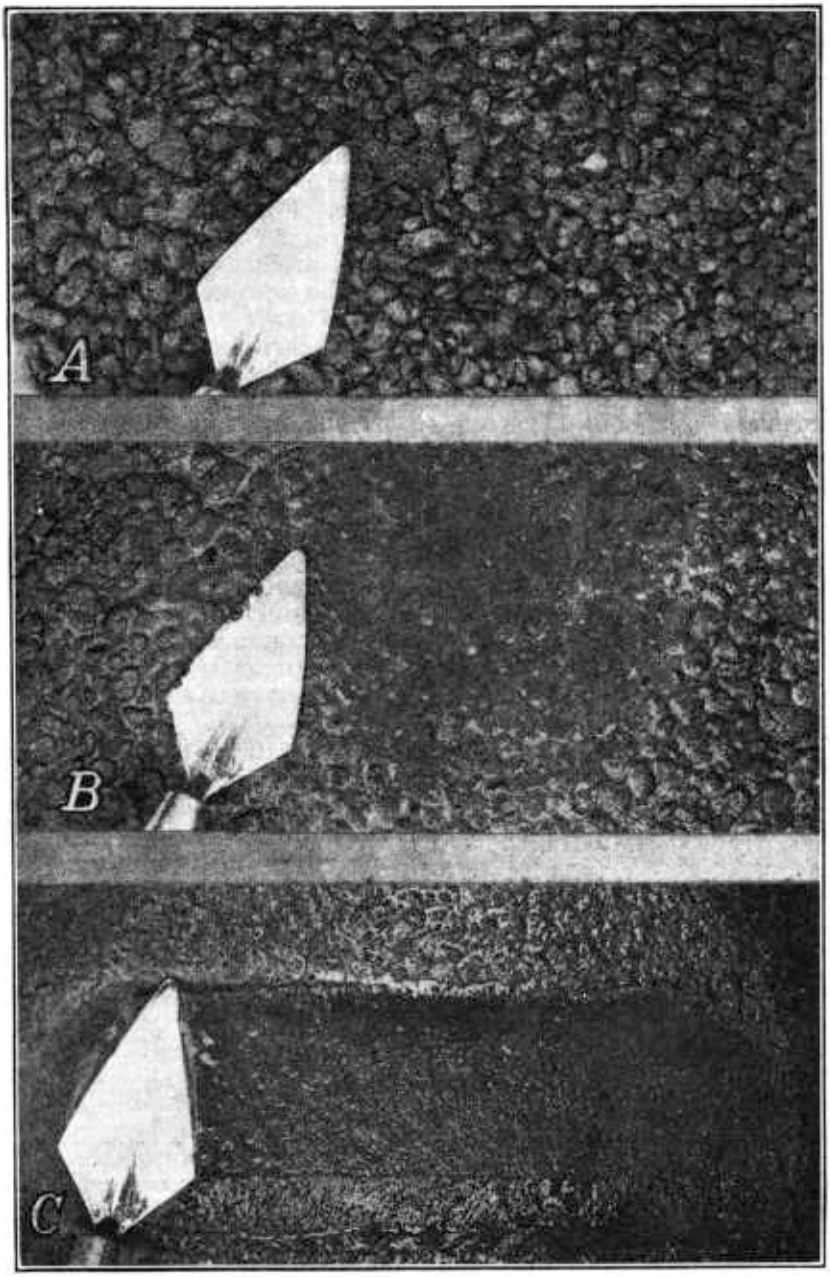


FIGURE 4.—*A*, Mixture lacking in cement-sand mortar; *B*, mixture containing the correct amount of cement-sand mortar; *C*, mixture containing an excessive amount of cement-sand mortar.

ranging in size from fine (excluding dust) to the largest, but in which the coarser sizes predominate. Coarse grading produces harsh mixtures, whereas too much fine material reduces the amount of concrete that can be made with a sack of cement. The main objective is to proportion the amount of sand to gravel so as to secure the largest quantity of concrete of a consistency suitable for the work.

## PROPORTIONING THE MATERIALS

### CONCRETE MIXTURES

The ideal concrete mixture is a plastic one in which all the spaces between the grains of sand are filled with the cement and all those in the gravel are filled with the cement-sand mortar. For practical considerations, a little more sand and cement than that required to just fill the empty spaces, are used.

A general guide to follow is to vary the proportion of sand according to the size of the gravel. For example, when the sand is moist, as under average conditions, use approximately equal parts of sand and gravel when the size of gravel ranges from one-fourth inch to three-fourths inch; use two-thirds as much sand as gravel when the gravel ranges from one-fourth inch to 1 inch; and use about three-fifths as much sand as gravel when the gravel ranges from one-fourth inch to 2 inches. If the sand is dry, which is seldom the case, use about 25 percent less.

Various proportions and consistencies have been tested by experienced engineers to determine which will, under average conditions, develop the greatest strength, best resist wear, and assure watertightness. The proportions given in table 1 are recommended for use in farm concrete work, provided that with the quantity of water specified a plastic mixture can be secured with the aggregates at hand. If the resulting concrete is not of the proper plasticity, or workability, the quantities of aggregate should be changed as described on page 9. Slightly leaner mixtures are sometimes used after a test has proved them to be suitable for the work at hand.

The proportions of materials in concrete are indicated by three successive numbers separated by colons, as 1:2:3, the first number referring to the cement, the second to the sand, and the third to the gravel, all measured by the same unit volume. The cubic foot is a convenient measure, because it is assumed that a sack of cement contains 1 cubic foot, although actually it contains only 0.95 cubic foot.

### MORTAR AND GROUT

When the gravel or other coarse aggregate is omitted from concrete, the mixture is generally called mortar, and the proportions are indicated by only two numbers, as 1:2, meaning 1 part of cement to 2 parts of sand. Mortar is used for plastering, stucco, top course of floors, and laying masonry units. The mortar usually recommended for general masonry work is composed of 1 part portland cement, 1 part stiff lime putty, and 6 parts sand. A mixture of cement and water only is called grout. It should be mixed to the consistency of very thick cream or very soft butter. Grout is used for coating outside surfaces of concrete to improve their appearance

and increase watertightness, for bonding old and new concrete, and for filling cracks or joints too small to admit mortar. See page 59 for the proper method of applying grout as a surface finish.

## QUANTITIES OF MATERIAL REQUIRED

A common mistake to be guarded against is to assume that the volume of concrete produced will be equal to the sum of the amounts of sand and gravel used. A 1:2:4 mixture, for instance, in which 2 cubic yards of sand and 4 cubic yards of gravel are used, will not produce 6 cubic yards of concrete because the sand will lodge in the spaces between the pebbles. If 6 cubic yards of 1:2:4 concrete are wanted it will be necessary to use 2.67 cubic yards of sand and 5.34 cubic yards of gravel.

The quantities of cement, sand, and gravel [2] required under average conditions for concrete of various proportions are shown in table 2. When bank-run gravel is used instead of sand and gravel, if the mixture has the correct proportion of sand and gravel, as given on page 11, consider a 1:4½ mixture equivalent to 1:2:4; a 1:5½ mixture equivalent to 1:2½:5; and a 1:7 mixture equivalent to 1:3:6.

TABLE 2.—*Approximate quantities of materials required for making 1 cubic yard of concrete in place*

[These quantities are approximate and may vary by 10 percent depending on the aggregate used]

| Proportions of the concrete or mortar | | | Quantities of materials | | |
|---|---|---|---|---|---|
| Cement | Sand | Gravel or stone | Cement | Sand (damp and loose) | Gravel (loose) |
| | | | *Sacks* | *Cubic yards* | *Cubic yard* |
| 1 | 1.5 | ---------- | 15.5 | 0.86 | ---------- |
| 1 | 2.0 | ---------- | 12.8 | .95 | ---------- |
| 1 | 2.5 | ---------- | 11.0 | 1.02 | ---------- |
| 1 | 3.0 | ---------- | 9.6 | 1.07 | ---------- |
| 1 | 1.5 | 3 | 7.6 | .42 | 0.85 |
| 1 | 2.0 | 2 | 8.2 | .60 | .60 |
| 1 | 2.0 | 3 | 7.0 | .52 | .78 |
| 1 | 2.0 | 4 | 6.0 | .44 | .89 |
| 1 | 2.5 | 3.5 | 5.9 | .55 | .77 |
| 1 | 2.5 | 4 | 5.6 | .52 | .83 |
| 1 | 2.5 | 5 | 5.0 | .46 | .92 |
| 1 | 3.0 | 5 | 4.6 | .51 | .85 |
| 1 | 3.0 | 6 | 4.2 | .47 | .94 |

## EXAMPLES OF ESTIMATING QUANTITIES

In estimating the amount of concrete in a given piece of work and the amounts of materials required, the unit of measurement is usually the cubic yard (27 cubic feet). The following examples will explain best the method of determining the quantities required.

**Example 1.**—A wall 9 inches thick, 12 feet high, and 30 feet long has a door opening 3 feet wide and 6 feet high, also a footing 18 inches wide and 9 inches deep. The concrete is to be of the proportions 1:2:4.

[2] Screened gravel, not bank run.

The volume of the footing is found by multiplying together the dimensions expressed in feet, thus: $1\frac{1}{2}$ by $\frac{3}{4}$ by $30=33\frac{3}{4}$ cubic feet. Similarly, the volume in the wall is $\frac{3}{4}$ by 12 by 30, less the door opening $\frac{3}{4}$ by 3 by 6, or $256\frac{1}{2}$ cubic feet. The total volume in footing and wall is $290\frac{1}{4}$ cubic feet $=10\frac{3}{4}$ cubic yards.

To find the necessary amounts of cement, sand, and gravel, multiply the quantities for 1 cubic yard as given in table 2 (line 8) by $10\frac{3}{4}$, and it will be found that 64.5 sacks of cement, 4.73 cubic yards of sand, and 9.57 cubic yards of gravel are necessary to build the wall.

**Example 2.**—A pavement 27 feet long, 4 feet wide, and 6 inches thick has a 5-inch base mixed in the proportions of 1 : 3 : 5 and a 1-inch surface mixed in the proportions of 1 : 2.

The volume in the base is 27 by 4 by $\frac{5}{12}=45$ cubic feet $=1\frac{2}{3}$ cubic yards.

The volume in the top is 27 by 4 by $\frac{1}{12}=9$ cubic feet $=\frac{1}{3}$ cubic yard.

Multiplying the quantities in line 12 of table 2 by $1\frac{2}{3}$ and those in line 2 by $\frac{1}{3}$, it is found that the base requires 7.67 sacks of cement, 0.85 cubic yard of sand, and 1.42 cubic yards of gravel, and the top requires 4.27 sacks of cement and 0.32 cubic yard of sand.

**Example 3.**—A circular tank 9 feet inside diameter has walls 6 inches thick, and 4 feet high (above the floor). The floor is 6 inches thick, the concrete is to be 1 : 2 : 4.

The volume in the floor [3] is $\frac{10}{2}$ by $\frac{10}{2}$ by $\frac{22}{7}$ by $\frac{1}{2}=39\frac{2}{7}$ cubic feet. The area of the larger circle is $\frac{10}{2}$ by $\frac{10}{2}$ by $\frac{22}{7}=78\frac{4}{7}$ square feet. The area of the smaller circle is $\frac{9}{2}$ by $\frac{9}{2}$ by $\frac{22}{7}=63\frac{4}{7}$ square feet. The horizontal area of the wall therefore, is $78\frac{4}{7}-63\frac{4}{7}=15$ square feet, and the volume is 15 by $4=60$ cubic feet.

The total volume in the structure is $99\frac{2}{7}$ cubic feet or $3\frac{2}{3}$ cubic yards. Multiplying the quantities in line 8 of table 2 by $3\frac{2}{3}$, it is found that the following material is needed: 22 sacks of cement; 1.61 cubic yards of sand; 3.26 cubic yards of gravel.

## FORMS

Forms are required to hold the concrete in place until it has attained sufficient strength to sustain itself and the initial loads to which it may be subjected. Concrete is plastic and will assume the shape of the form; thus any imperfection or impression on the face of the forms will be reproduced.

Wood is commonly used for forms, though various other materials sometimes are better adapted to special conditions. Cast iron, for instance, is suitable for casting small objects that are to be reproduced in quantities, such as concrete block or tile; plaster of paris, glue, or moist sand are employed for casting ornaments or to produce a smooth surface; sheet metal is suitable when the forms can be used repeatedly, and for circular structures such as silos. When the sides of an excavation are not likely to cave in, earth may serve as a form.

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[3] A practical rule in finding the area of a circle is to multiply the radius (one-half the diameter) by itself and the product by $\frac{22}{7}$. In finding the volume in the wall of a circular structure, such as a silo or tank, the area of the circle formed by the inside circumference is deducted from the area of the circle formed by the outside circumference and the remainder is multiplied by the height.

### WOOD FORMS

Wood for forms must be of a kind that is easily worked and will retain its shape when exposed to the weather. White pine is the best wood but is seldom used because of its cost. Spruce, yellow pine, and fir are satisfactory woods for forms and are best if used while partially green or unseasoned.

The edges of boards should be surfaced, tongued and grooved, or beveled in order to obtain a tight form, so that the soft mortar will not ooze out. A better surface is secured if the boards are dressed on one side and are free of loose knots or other imperfections.

Various kinds of hard or pressed boards manufactured in pieces 4 feet wide and 4 to 12 feet long can be used for producing smooth concrete surfaces. Such material must be carefully braced or used only as a lining inside of wood forms.

As forms must be removed, they should be so planned that they can be taken down without destroying the lumber, especially if the boards are to be used for sheathing or again for forms. Therefore the nailing of the boards to the support should be only sufficient to keep them in place until the concrete has hardened. Greasing the form surface next to the concrete with crude oil, crank-case oil, soap solution, or linseed oil will prevent the concrete from adhering and will facilitate removal. These materials should not be applied to forms which come in contact with concrete surfaces that will later be painted or stuccoed.

### METAL FORMS

Metal forms can be used to advantage when the work involved is to be repeated many times. If the forms have to be altered, the relative costs of wood and metal forms should be carefully determined. Metal forms of various types and designs may be purchased. Although the first cost may be high, use of them may lower the total cost when the work is such as to warrant it.

### REMOVAL OF FORMS

The period of time after which forms may be removed varies according to conditions. Warm weather and richness and dryness of the mixture all tend to hasten setting and hardening of concrete. The character of the structural member and the loadings also must be considered. Thus, an unloaded wall 12 inches or more thick may be stripped of forms in from 1 to 3 days, while the forms of thinner walls should remain in place from 2 to 5 days. Slab forms and the sides of beam and girder forms may be removed in from 6 to 14 days if the span is not over 7 feet. The bottoms of beam and girder forms, even though of a span less than 7 feet, should remain in place and braced from 10 to 14 days and even longer. Experience is the best guide to the time of removal, but if there is any doubt ample time should be allowed, especially in cold weather. If the forms are removed before the concrete is well set, edges and surfaces may be damaged.

### BUILDING AND SETTING FORMS

Concrete, while plastic, exerts a great pressure on the confining walls, necessitating rigid tying and bracing of the forms to keep them from bulging out of alinement. The effect of a bulging form is

corrected only at considerable trouble and expense; hence when the nature of the structure permits, it is advisable to pour the concrete to a depth of not more than 2½ or 3 feet and allow it to set or become firm before pouring more. The forms for tanks or cisterns must be built to withstand pouring concrete in one operation for reasons stated on page 27.

The form most used in concrete construction is that for a straight wall. The methods of building such a form apply in general to the forms for most structural work, though modifications, as suggested in various illustrations throughout this bulletin, may be necessary to meet particular conditions.

The straight-wall form may be built continuous (figs. 5 and 6), or in panels of a size convenient to handle, and from stock lengths of

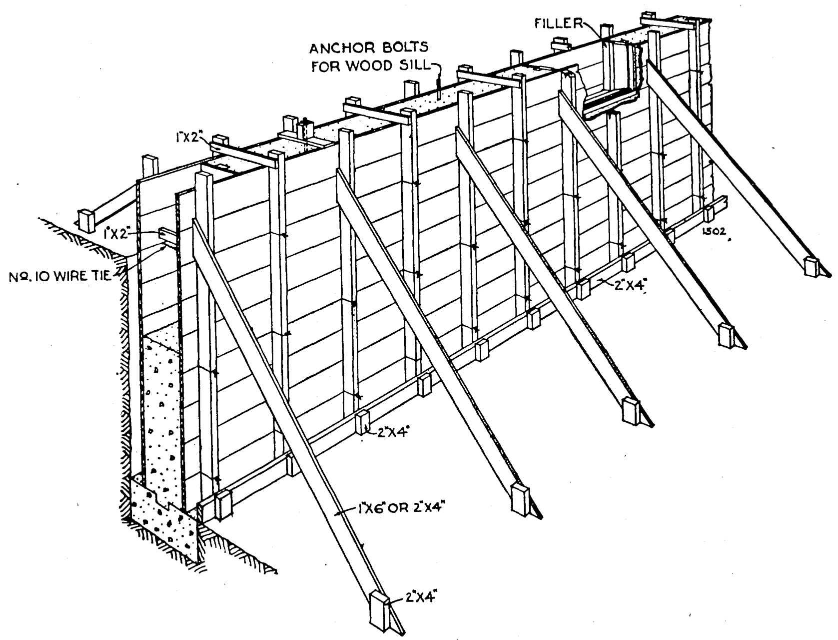


FIGURE 5.—Form for basement or cellar wall. The earth may be used as an outside form if it is sufficiently firm.

lumber (fig. 7). Generally the face boards are placed horizontally and secured to studs or posts. The face boards may be 1 or 2 inches thick and from 6 to 10 inches wide, preference being given to the narrower widths which are less likely to cup or warp. The thickness should depend on the spacing of the studs, the number of times the forms are to be used, and the depth of concrete to be placed. Ordinary sheathing, if the joints are made tight, is satisfactory for foundations of dwellings if 2- by 4-inch studs are spaced 18 inches on centers. The studs for a long, high form should be 2 by 6 inches or 4 by 6 inches, spaced from 2 to 3 feet on centers. The studs of the inside and outside forms must be tied together to prevent spreading; this is conveniently done with no. 10 or no. 12 wire, as shown in figure 5, or with ½- or ¾-inch bolts, which is more expensive. Bolts should

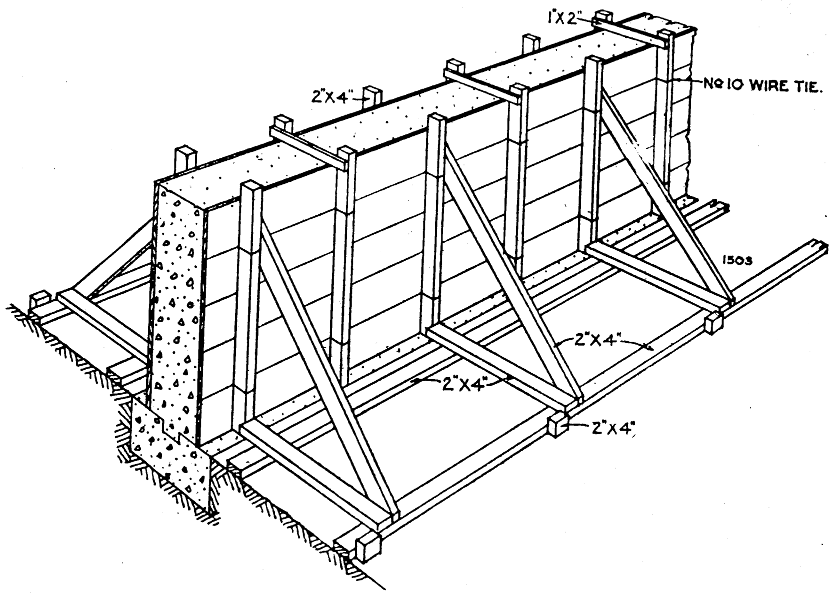


FIGURE 6.—Straight wall form for level ground.

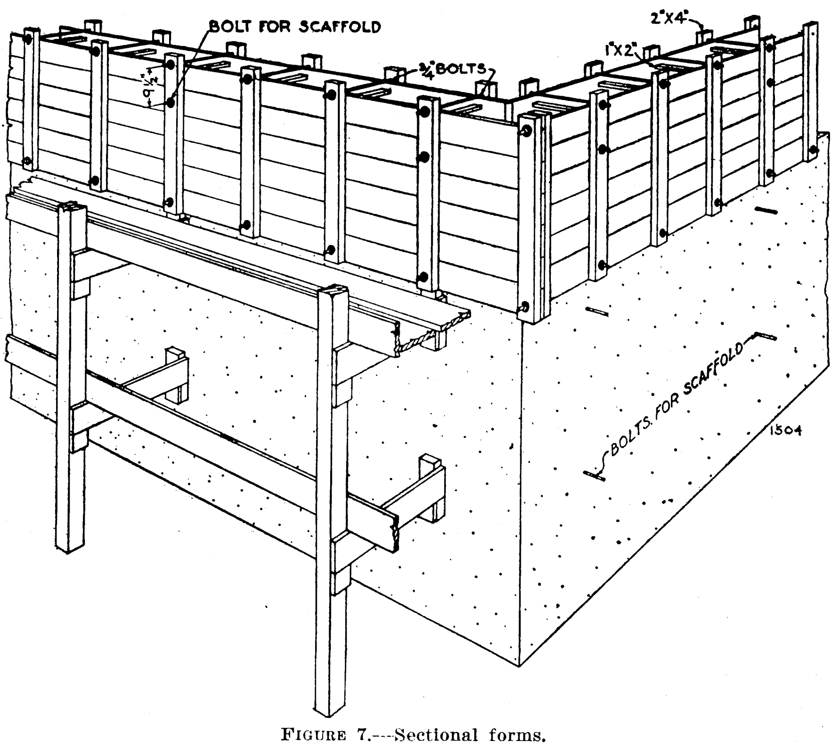


FIGURE 7.---Sectional forms.

be greased to facilitate removal. Temporary spacers of wood, 1 by 2 inches, of length equal to the wall thickness, should be used to prevent the forms from drawing together when the wire or bolt is tightened. They should be spaced at the ties, but need not be at every wire, and are knocked out and removed as the concreting progresses.

The ties should be spaced on each stud about $2\frac{1}{2}$ feet vertically. If a greater depth than 3 feet of concrete is to be poured within 30 minutes, the ties should be closer together vertically at the bottom of each pouring. The thickness of the wall does not affect the number of ties. When the forms are removed the wires should be clipped close to the face of the concrete and punched back, unless the surface is to be stuccoed. If a pit hole is caused by punching back the wire, it should be pointed up with mortar which should then be rubbed to make it blend with the rest of the surface.

Circular forms may be built as shown in figure 8. The sheathing

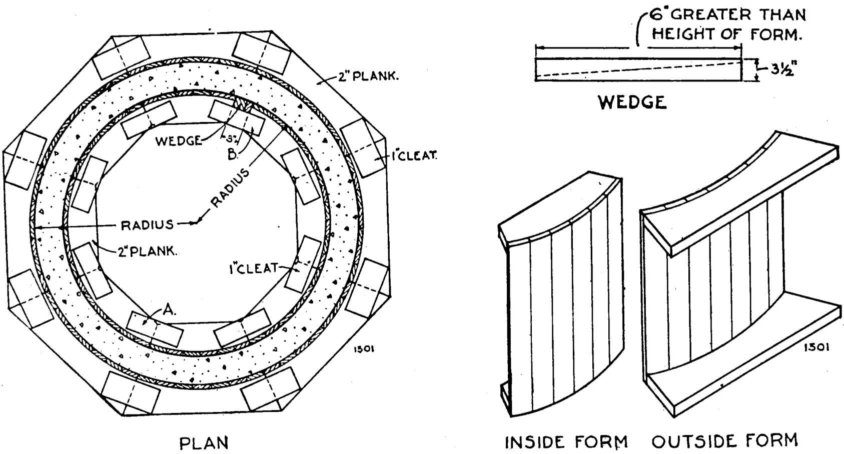


FIGURE 8.—Suggestion for circular form.

is generally of wood 4 to 6 inches wide, or sheet metal, and if of wood is laid perpendicular to the battens. In forms of small diameter, sheet metal is necessary if a smooth surface is desired, as the 4-inch boards cannot be made to conform to a true circle. The radius used for cutting the battens of the inner circle should be the thickness of the sheathing less than the inside radius of the structure, and for the outside battens should be the same amount greater than the outer radius.

## COST OF FORMS

The cost of forms is frequently a large item and depends not only on the amount of material but also on the labor required. Complex forms and forms for a small cross section often cost more than the concrete. The cost of forms should be determined from local sources for each job as it is not feasible to give methods of estimating in this bulletin. The following general guide, however, will be helpful in approximating the materials and time required for building basement-wall forms similar to those shown in figure 6.

MATERIAL AND LABOR FOR BUILDING FORMS FOR BASEMENT WALLS, PER SQUARE FOOT OF CONTACT AREA

| | | |
|---|---|---|
| Sheathing ⅞ by 8 inches | feet, board measure | 1.2 |
| Studs 2 by 4 inches | do | .93 |
| No 12 wire | pound | .02 |
| Eightpenny nails | do | .04 |
| Twentypenny nails | do | .01 |
| Labor on sheathing | hour | .03 |
| Labor on studs | do | .03 |
| Labor in removing forms | do | .02 |
| Loss of time reworking lumber | do | .006 |

If the forms are to be salvaged for framing and sheathing, deduct the following from the costs:

| | | |
|---|---|---|
| Salvaged sheathing | foot, board measure | 0.96 |
| Salvaged studding | do | .87 |

**Example.**—Determine the labor and materials required for building the forms for the wall described in example 1 (p. 12).

Wall 12 feet high, 30 feet long=360 square feet
Forms on both sides=720 square feet contact

Multiply each of the nine items in the tabulation above by 720 to find the total quantity of different materials and labor needed; then multiply each of the totals by the local price of each material or wage. The sum will be the actual cost of the forms without profit. If the forms are to be used again, multiply the items salvaged by 720 and the price of lumber and deduct the amount from the cost previously found.

## MIXING

### PREPARATION OF EQUIPMENT

Annoyance and money may be saved by planning, before starting to mix, the location of the mixing equipment for convenience in placement of the concrete and in access to the materials. Often the mixing board can be located so that, by moving it once or twice, most of the concrete can be shoveled directly into the forms. Eight feet is about as far as it is profitable to carry concrete with shovels; it is more economical to wheel material 10 to 25 feet. Plank runways should be provided when material is to be wheeled, because more material can be handled in a given time and the wear and tear on men and equipment is not so great. The planks used in the runways should be thick enough to sustain the weight passing over them and should be 10 to 12 inches wide to give foot room. They should be anchored securely and made rigid, as springy or loose boards retard progress of the work. Smooth joints in the planking will prevent bumping and stumbling.

### LABOR REQUIRED IN MIXING

The number of men required is determined by the amount of concrete to be placed in a given time, the method of mixing, and the size of the batch; that is, the number of sacks of cement mixed at one time. The amount of concrete one man can mix by hand in a day depends on the experience of the man, the layout of the work, and other duties required of him. One man should average 1½ to

to $1\frac{3}{4}$ cubic yards of concrete in 8 hours, including mixing by hand and wheeling not more than 50 feet. A three-man crew using a small mixer should place 8 to 16 cubic yards in the same time. An experienced finisher with helper can mix, place, and finish 90 square feet of topping (one-half to 1 inch thick) on sidewalks or floors in 1 hour, while it will require $3\frac{1}{2}$ hours for them to mix and place 1 cubic yard of base concrete by hand, or $2\frac{1}{2}$ hours by machine. One man should be able to mix and place 100 square feet of cellar floor 4 inches thick in 10 hours.

If the site of mixing is more than 50 feet from the forms, or if the concrete must be elevated, more time is required. Concrete can be deposited in mass considerably cheaper than in thin sections or around closely spaced reinforcing.

The gang for a one-bag batch may consist of three men, but a larger number make a more efficient force, for when the concrete is mixed by hand the men can take turns at the various tasks and will not tire so easily. The assigning of tasks so that each man's time fits into that of the others requires considerable study and is one of the chief factors making for economy if labor is hired.

### MACHINE MIXING

Good concrete can be mixed by hand or machine. The quantity of concrete work in prospect is the factor that determines the more economical method. A small amount (say 100 to 200 cubic yards) does not warrant the purchase of a machine, but it is often feasible and economical to hire a machine from a neighbor or contractor if the quantity of concrete to be placed is more than 15 cubic yards. In many localities it is feasible to purchase ready-mixed concrete delivered to the job ready for placing, and it may be economical to do this when suitable equipment or labor is not readily available.

A mixer should be purchased only after careful consideration of the amount and character of the work to be done and the conditions affecting its use. There are numerous types of batch mixers of various capacities from 2 to 30 cubic feet of concrete per batch. A one-bag batch machine is most suitable for general work, though there are smaller mixers that are sometimes handy. Some of the smallest sizes are operated by hand, but the medium and larger sizes are power operated. Mixers can be had with or without the power plant attached and may be stationary or on wheels which facilitate moving to different sites. Engines used for sawing wood, the larger ones used for pumping water, and tractors furnish sufficient power to operate a mixer of average size. Engines of 1 horsepower will operate a small mixer.

Directions for operating a mixer are generally furnished with the machine. The tendency is to use too much water in mixing concrete in a machine. The consistency of the mixture should be as described on page 8. The mixing should be continued for at least a minute after the drum has been charged, but a better mixture is secured if 2 minutes are allowed. The rate of rotating the mixer has little influence on the quality of the concrete. Thorough mixing is dependent on the length of time allowed in actually mixing and on not overloading the drum. At the end of each day's work the machine

should be thoroughly washed, and when not in use it should be well greased and covered.

### HAND MIXING

Hand mixing is practical on the farm unless a large amount of work is to be done at one time. Few tools are needed, and, as a rule, only farm help need be employed. The following tools in addition to those illustrated in figure 9, will be needed in mixing and placing plain concrete: Two or more square-end short-handle and one or

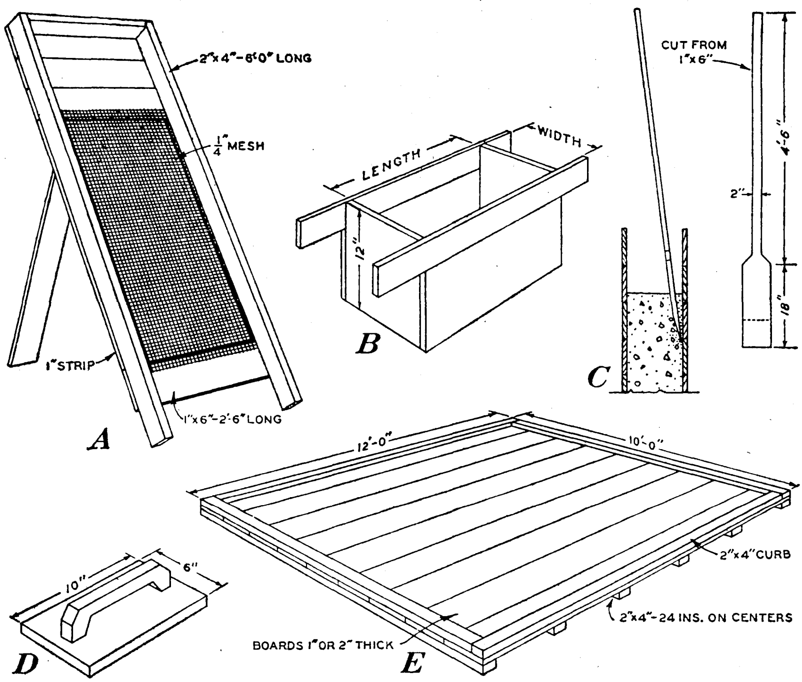


FIGURE 9.—Tools used in mixing concrete: *A*, screen; *B*, bottomless measuring box; *C*, wooden spade for working concrete in the form; *D*, wooden float; *E*, mixing board.

more pointed shovels, one heavy garden rake, one sprinkling can or bucket, one 50-gallon barrel, one bucket for measuring water, and two wheelbarrows with metal trays. The number of shovels and wheelbarrows needed will depend on the size of the batch, the number of men mixing, and the lay-out of the work. Long-handle pointed shovels will be found more convenient at the sand and gravel piles.

TABLE 3.—*Inside dimensions of measuring boxes for concrete aggregates*

[1-sack batch, box 12 inches deep]

| Proportions of concrete | Box for sand | Box for gravel | Proportions of concrete | Box for sand | Box for gravel |
|---|---|---|---|---|---|
| | *Feet* | *Feet* | | *Feet* | *Feet* |
| 1:1:2 | 1 by 1 | 1 by 2 | 1:2½:5 | 1¼ by 2 | 2 by 2½. |
| 1:1½:3 | 1 by 1½ | 1 by 3 | 1:3:5 | 1½ by 2 | 2 by 2½. |
| 1:2:4 | 1 by 2 | 2 by 2 | 1:3:6 | 1½ by 2 | 2 by 3 |

The bottomless box is necessary for convenient and accurate measurement of the sand and gravel. Where wheelbarrow measurement of materials is practiced, as in charging a mixer, the capacity of the wheelbarrow should be determined by use of a measuring box. The box may be made as illustrated. The dimensions in table 3 are of boxes for use in measuring quantities for mixtures of various proportions, assuming that one sack of cement is used in a batch. If two sacks are used in a batch the boxes should be filled twice.

The mixing board should be located in convenient relation both to the supply of materials and to the work, and should be watertight and level. The measuring box is placed on the board, about 2 feet from one of the longer sides, and filled level with sand; the box is then lifted away and the sand spread in a 3- or 4-inch layer. The cement is spread as evenly as possible on top of the sand. Two men with shovels, standing on opposite sides of the pile, turn the sand and cement in such a way that the aggregates are thoroughly mixed. In turning the material it should not be simply dumped off the shovel, but should be slid off the end and spread with a dragging movement of the shovel, so that the two constituents will be mixed as they are turned. The mass should be turned two or three times, or until it is of uniform color and there are no streaks of either sand or cement. A man with a hoe or rake may assist by raking the top over as the two men turn the sand and cement.

When the sand-cement mixture is of uniform color it should be spread in a thin layer and the measuring box placed on top. The box is filled with gravel and then removed, the gravel being spread over the sand-cement mixture. The mass is wetted with about one-half the quantity of water to be used, care being taken not to wash away any of the cement. The materials then should be turned over in much the same manner as was the sand and cement; the whole mass being turned and dragged back toward the mixers with the square end of the shovel. The wet gravel picks up the sand and cement as it rolls over when dragged back. The mixing should be continued until the mass is uniform, water being added to the dry spots during the mixing until the desired consistency is obtained.

Experience counts considerably in mixing concrete with the least amount of labor; ordinarily three or four turnings are required to mix the materials thoroughly. After the final turning, the concrete should be shoveled into a compact pile ready for placing in the forms.

## PLACING

The mixed concrete should be deposited in the forms within 20 to 30 minutes of the time the water is added to the cement, as it begins to set or harden after this time, especially in warm weather. To disturb the concrete after the set has begun may cause it to lose some of its strength, the extent of the injury depending on the seriousness of the disturbance.

Concrete which has set before it can be placed in the forms should not be tempered or softened with water, but should be discarded. To prevent delay in placing, all forms should be examined before the mixing is begun to see that they are properly braced, that all chips or other loose particles are removed, that the surface of con-

crete which has set has been properly roughened and wetted to assure a bond, as described on page 23, and that all reinforcement, bolts, inserts, etc., are properly located and secured.

At the lunch period and at the end of a day's work, the mixing board and equipment should be thoroughly washed, to avoid many pounds of weight being needlessly carried around by the men. It will save time and wear and tear of equipment incident to cutting away the concrete with a cold chisel. The addition of a pound in the weight of tools will lower the efficiency of the workers.

In depositing concrete in the forms, care should be taken that the materials do not separate.

If the mixing is done close to the place of depositing, the concrete may be shoveled into the forms directly or through a chute.

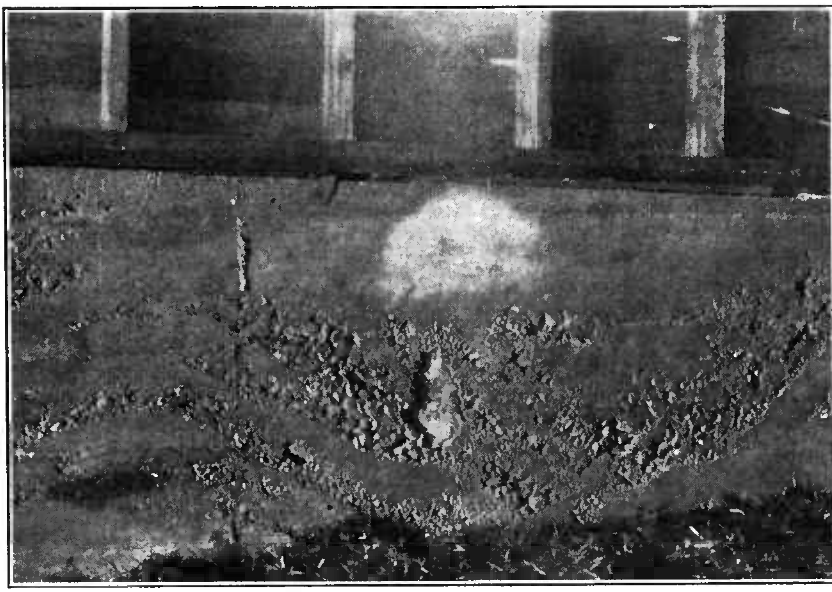

FIGURE 10.—Result of leaky forms and poor placing. The soft cement mortar ran out, leaving areas of honeycombed surface not only harmful but unsightly.

If it is necessary to lift or transport the concrete, buckets and wheelbarrows are convenient containers. The concrete should be deposited in horizontal layers, preferably not over 6 inches thick, and a spade, paddle, or straightened hoe should be worked up and down against the forms to push the coarse material away from the surface. The spading will also eliminate impounded air that may form pockets in the mass and will settle the concrete in the forms, thereby making a smoother and more impervious surface. Tapping the forms with a hammer is a very effective way of securing a smooth surface. Figure 10 shows the result of improper spading.

When the concrete is mixed to a flowing consistency, as for a tank with thin walls or where reinforcing is spaced closely, water will accumulate as the successive batches are poured and a weak or porous concrete will result, probably with separation of the mortar and gravel. To avoid this and to permit using the least quantity

of water in the concrete mix, the first batch placed in the forms should be a fairly wet mortar made of the same quantities of cement and sand as used in the concrete. The succeeding batches should be of concrete mixed only wet enough to produce a plastic mixture as the mortar which was first deposited works its way up through the mass.

When concrete becomes sloppy during placing, the succeeding batches should be mixed to a stiffer consistency until excess water is absorbed and does not rise.

Scum or laitance is likely to form on concrete, especially if an excess of water accumulates in the forms when placing, and in such case seams or planes of weakness will occur unless all of the concrete is poured in one operation.

Fresh concrete will not bond readily to concrete that has hardened, and a seam may be formed that will permit water to seep through. When bonding fresh concrete to that which has been in place for a short time, it is usually sufficient to roughen the hardened surface with a pick or other means so as to expose the gravel or stone, and to clean off all loose particles. The top surface of concrete can be roughened just before it hardens, to provide a bond for the next day's work. The hardened concrete should be soaked with water, the excess water removed, and the surface then given a coat of grout just before the new concrete is deposited.

When the pouring of a wall is to be discontinued for some time, provision for bonding future work should be made. This can be done by placing short steel dowels in the concrete when it is poured, or a rebated joint or groove may be made, as shown in figure 11. In bonding a new wall to old concrete, holes should be drilled for dowels, which should be grouted in, and the old surface should be roughened, cleaned, and wetted; or a groove may be cut in the old wall to receive the new concrete.

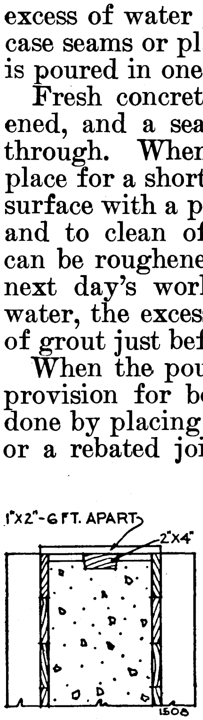

FIGURE 11.—Method of forming horizontal rebate.

Concrete should not be deposited under water unless it is impractical to pump out or drain the forms, as there is always uncertainty as to the results. Where it is necessary to place the concrete under water, there should be expert supervision to prevent the cement from being washed away.

## CURING

After the concrete has been placed, care should be taken that it does not dry too quickly, and in hot weather it must be protected from the sun and from drying winds. Exposed surfaces and objects made of dry mixtures should be sprayed thoroughly with water twice or oftener each day or otherwise kept moist for a week or 10 days. Materials commonly utilized for protecting concrete while curing are canvas, burlap, boards, layers of moist sand, and straw. These should be placed as soon as practicable without marring the concrete surface and be kept continuously moist. Vertical surfaces are more difficult to protect than horizontal surfaces; forms left in place during the curing period afford good protection.

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## PROTECTION IN COLD WEATHER

If suitable methods are used, good concrete work can be done in cold weather, but with more difficulty and at somewhat greater cost than when the weather is warm. Ordinarily it is best not to attempt to do concrete work during freezing weather; many building codes do not permit it. However, the extra cost at times may be warranted by urgent need of the structure or by the fact that the concrete work carried on in winter will not seriously interfere with regular farm operations.

Every reasonable effort should be made to prevent concrete from freezing until it has set, since it may be permanently weakened if freezing occurs. Moreover, low temperature retards the setting and hardening of concrete; therefore, even though the temperature is not at the freezing point, the concrete should be protected and special care taken not to subject it to loads. The forms should be kept in place until there is no doubt that the concrete is properly hardened. Hot water may be poured on the concrete to make sure that the hardness is due to setting and not to freezing. Any ice and frost should be removed from the forms and reinforcement by warming the surfaces. Care must be taken to thaw out the ground before placing concrete upon it. Excavations should be kept from freezing by coverings of straw or other suitable materials.

When concrete has frozen before setting, the proper course is to keep it frozen by ample coverings unless the means for thawing are sufficient to be effective. Steam is the best medium for thawing frozen concrete, and stoves the next, but if these methods are to be economical and effective the concrete must be enclosed. It is advisable to wait until the weather moderates before thawing the concrete and to keep constant watch on the work to guard against fires getting low, especially if there is a drop in temperature, and also to make sure of a uniform distribution of heat. Heat must be supplied until there is no doubt that the concrete has been thoroughly thawed and has hardened. Concrete that has been frozen once may, with proper care, attain its ultimate strength, but should it freeze a second time the chances of saving the work are very slight.

### USE OF HEAT

Perhaps the most satisfactory method of keeping concrete from freezing is to heat the materials and to inclose or cover the completed work for a few days or until most of the water has disappeared and sufficient strength has developed. When the weather is cold but not freezing, heating the materials will be sufficient. The concrete when placed should be between 70° and 100° F. and should be maintained at about 50° for at least 5 days. If a freeze is expected the concrete work should be protected by enclosures of wood, paper, or canvas, over which, if the surface is horizontal, may be spread a 6- or 8-inch layer of straw. Earth on top of straw affords good protection. Manure should not be used to protect fresh concrete, since the acids in it are destructive and cause unsightly stains. Splits or other openings in coverings may expose parts of the work to freezing temperatures. If the temperature drops to about 20°

it will be necessary to arrange the covering so that live steam can be turned in between it and the concrete or so that heat may be supplied from stoves or salamanders.

Mass work, except in very cold weather, will not require as careful protection as thin sections and, as a rule, the forms are sufficient if the exposed parts are covered.

The water can be heated sufficiently for use in concrete (not to exceed 150° F.) in kettles on stoves, in steel drums over open fires, or by steam from a boiler.

For the sand and gravel an efficient heater can be made of a metal smokestack or sheet metal bent to form an arch, placed horizontally with a fire in one end. The materials are piled over the stack, but not so high that their weight will crush the pipe. Small quantities of sand and gravel may be heated (not beyond 140° F.) on top of a metal plate with a fire under it, but the materials should be heated separately to keep them from becoming mixed. If a small boiler is available it may be economical to use steam for heating the sand and gravel. Steam is effective when forced from nozzles into the piles or circulated through perforated pipes placed under the material. If the piles are covered with canvas or other material they will retain much of the heat.

## USE OF ADMIXTURES

Chemicals intended to hasten the setting of concrete should not be used as a substitute for heating water and aggregates, nor for furnishing the proper protection to the concrete. In general they are not recommended. High early-strength cement, which has recently become available, can be used to advantage instead of adding accelerators to ordinary cement and eliminates the uncertainty that may result from the misuse of admixtures. Where admixtures are used in important work, the rate of hardening of the concrete should be determined by trial batches made from the brand of cement and the brand of accelerator selected, as chemicals react differently with different brands of portland cement.

The best results with calcium chloride are obtained by using 2 to 4 percent of the chemical by weight of cement. The calcium chloride should be dissolved in the mixing water. If 2 pounds of calcium chloride are to be used for each bag of cement, a solution containing 1 pound per quart of water should be made and 2 quarts of this solution added to the mixing water for each bag of cement. The amount of the solution should be included as water, and the amount of mixing water specified should be reduced by this amount.

Common salt (sodium chloride) does not cause early setting and should never be used to lower the freezing point of concrete. The addition of 5 percent of salt to the mixing water reduces the freezing point only 6°, but decreases the strength of the resulting concrete 30 percent. Salt forms a white efflorescence on exterior surfaces, and in reinforced work is likely to corrode the steel.

## CONTRACTION AND EXPANSION JOINTS

Concrete expands and contracts with changes in temperature, causing cracks to appear. Contraction cracks occur in thin sections exposed to wide variations in temperature and are common in side-

walks; therefore, large stretches of concrete should not be laid without breaks or spaces to allow for the changes in size. The spaces should be filled with tar or some similar material that will yield or give when the concrete expands. A joint like that shown in figure 12 is frequently used for thick walls. After one section of the wall has been poured and before the next is poured the abutting end is covered with alternate layers of tar and felt, the thickness of the joint depending on the length of the section and the exposure. In long or high walls and in watertight work, steel is used to take care of contraction. Important structures in which temperature reinforcement is necessary should be designed by one experienced in concrete design. Types and location of joints are recommended under the discussions of special structures, beginning on page 28.

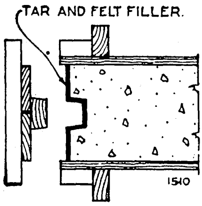

FIGURE 12.—Expansion joint showing rebate form removed and filler in place.

## REINFORCED CONCRETE

Concrete is strong in compression but has little resistance to forces tending to pull it apart; therefore steel is used to reinforce those sections subjected to stretching. The amount and location of steel for certain structures commonly built on farms are indicated later, in the discussions of particular structures.

Barbed wire, old fencing, and scrap or rusty iron are not suitable for reinforcement. Loose rust should be cleaned off the rods, and they should be free of oil and grease.

In general, all reinforcement should be protected by a covering of at least three-fourths inch of concrete, and care must be taken to place the concrete under and around the steel to secure a good bond.

## SURFACE FINISH

Joints and imperfections in the forms are reproduced on the concrete surfaces. Patches of honeycomb and rough places are left where the mortar has run out of the forms or where the concrete has not been properly placed. Such imperfections do not necessarily affect the strength of the concrete, but they do detract from the appearance (fig. 10). Too often the finishing of the concrete work in even the more important farm buildings is neglected. With little extra trouble exposed surfaces can be given a finish that will add to the attractiveness and hence the value of the completed work. Rubbing off the form marks and pointing up depressions or holes greatly improves the appearance of the work. The rubbing may be done with a wooden float or hard-burned brick, using a little sand and water as an abrasive, and a 1:2 mortar is good for pointing up. The surface can be worked best if the forms are removed within 24 hours, or before the concrete has set too hard. After the concrete has hardened it may be necessary to use a carborundum block for rubbing.

A pleasing finish can be had by scrubbing the surface with a stiff fiber or wire brush, using plenty of water to wash off the loosened particles. The work must be done while the surface is workable, for

if the concrete is too green or soft the aggregate will break out and if too hard the work cannot be done effectively.

Artistic effects can be secured by picking or tooling the surface with a bushhammer, toothed chisel, or pick. For such treatment the concrete should be 2 or 3 weeks old to prevent breaking out the aggregate. Corners are frequently given a rubbed finish because they are likely to be broken off by the hammering if the tooling is done too close to the edges. Different surface finishes are described in connection with the later discussions of particular structures.

## WATERTIGHTNESS

Practical watertightness in the concrete itself, which is a desirable quality for several reasons, may be secured by using a fairly rich mixture properly proportioned. Special ingredients, membranes, and surface coatings need not be used except where poor workmanship and poor site conditions exist.

First-class workmanship and special attention to details are required to secure watertight concrete. The essential requisite is that the voids be filled and the concrete cured under favorable conditions as described on page 23. A lean mixture may be made more impervious by using hydrated lime which tends to fill the voids and makes the concrete flow easily. More cement in the mixture would serve the same purpose and at the same time increase the strength. The lime should not be in excess of 10 percent of the weight of the cement, and under no circumstances should unslaked lime be used.

The materials for watertight concrete must be well graded, so as to obtain a maximum density; that is, enough sand must be used to fill the spaces between the gravel or stone and enough cement to fill the spaces between the grains of sand. A 1:2½:4 mixture for walls 8 inches or more in thickness is practically impermeable in ordinary construction, but if a head or pressure of water is to be resisted a 1:2:3 or richer mixture may be necessary. The consistency is very important. A sluggishly flowing consistency is best, for if the concrete is too wet the mortar may separate from the stone, leaving air spaces; if too dry, the mass may be porous. The proportions and consistency must be accurately maintained for each batch, and the concrete must be exceptionally well mixed.

It is necessary to exercise great care in placing the concrete. Where practicable, the structure or object should be poured in one operation to avoid leaky joints, but when this is not possible precautions should be taken to secure a tight joint between concrete of different ages. The surface of concrete which has set must be cleaned of dirt and scum down to the true concrete. This surface should then be well wetted and painted immediately with a creamy mixture of cement and water before the new concrete is placed. A good plan, when discontinuing work on structures intended to hold liquids, is to embed a 6- or 8-inch strip of tin or thin sheet metal to half its width in the concrete so that the other half will project into the new concrete.

Contraction and expansion must be controlled to avoid leaks. To guard against cracks due to unequal settlement or other causes, most concrete designed for watertightness should be reinforced. In some mass work, special contraction joints (p. 26) may be necessary.

Rules cannot be given for the use of reinforcement and contraction joints, as the requirements in each case vary.

There is a great difference between making a watertight concrete and making a watertight structure. A wall of good monolithic concrete should not be relied upon for watertightness without providing other protection when it is known that the ground-water level is high and the site is poorly drained, especially if there are underlying strata of clay. This is especially true if dry cellars are to be provided. Drain tile around the footing of the foundation to conduct ground water to an outlet at a lower level should always be installed if the site is poorly drained. Drain tile used in this manner and a good watertight concrete will generally provide a dry basement without the necessity of expensive exterior coatings.

Where poor workmanship is likely or where considerable damage and inconvenience may result in case of leakage, the membrane treatment, used in addition to properly proportioned concrete and drain tile, while the most expensive method of waterproofing will probably give the most reliable results. Farmers' Bulletin 1572, Making Cellars Dry, describes the proper method of laying drain tile, applying membraneous coatings, and waterproofing.

## ALKALI-RESISTANT CONCRETE

In those sections of the United States where soil alkalies occur, the waters may contain magnesium sulphate (Epsom salts) and sodium sulphate (Glauber's salt). These salts, if present in considerable quantities, are destructive to concrete as made for ordinary farm structures. Any soil water that is bitter to the taste, even very slightly, should always be regarded as a possible source of trouble. This is especially important in those localities where concrete drain tile is used extensively and should be considered also in connection with culverts, foundations, and all other types of concrete structures in direct contact with the soil. The State agricultural colleges generally are informed as to the precautions to be observed in using concrete in the localities where soil alkalies are found.

## FARM STRUCTURES MADE OF CONCRETE[4]

While concrete has a wide range of adaptability, the same mixture and same method of handling cannot be used for every type of structure. Certain qualities must be developed by handling the concrete in different ways in order that it may have properties suitable for the work at hand.

### PAVEMENTS

Walks, floors, and similar pavements involve simple operations and can easily be made if care is taken to plan the work and execute it by approved methods. The principles involved in building

[4] Information concerning some farm structures of concrete other than those described herein are given in Farmers' Bulletins 1227, Sewage and Sewerage of Farm Homes; 1243, The Border Method of Irrigation; 1342, Dairy Barn Construction; 1448, Farmstead Water Supply; 1584, Feed-lot and Ranch Equipment for Beef Cattle; 1638, Rat Proofing Buildings and Premises; 1658, Farm Water Power; 1701, Corncribs for the Corn Belt; 1703, Reservoirs for Farm Use; 1818, Mechanical Milk Cooling on Farms; and 1820, Silo Types and Construction. Other bulletins and plans for various structures are available from most of the State agricultural colleges and experiment stations. Inquiry concerning them should be addressed to the extension agricultural engineer at the college.

various types of farm pavements are the same. The only practical differences between walks, feeding floors, barn floors, etc., are the arrangement of the forms for convenience in handling the work and the methods of shaping and finishing the top surface. Concrete for highway paving should be made in accordance with definite specifications, approved by the proper authorities.

### PREPARATION OF SITE

The first step in the construction of a pavement is the preparation of the site. The ground should be cleared of all tree roots and vegetation and graded to the proper slope or level. Fills necessary in grading should be made in horizontal layers, about 6 inches thick and thoroughly rammed or otherwise compacted, to avoid settlement after the concrete is laid.

After the topsoil has been removed and the site properly graded, an excavation must be made over the area of the pavement, equal in depth to the thickness of the concrete slab plus the sub-base, if one is required. Care must be taken to secure uniform depths so the slab will have its full thickness throughout.

A porous sub-base is necessary for both outside pavements and inside floors where the soil is heavy and holds water. Also a sub-base is advisable if it is necessary to fill in the space below the floor with loose dirt. Ordinarily 6 to 8 inches of gravel, clean coarse sand, or cinders is sufficient to form the sub-base, which should be well compacted by wetting and tamping. Where the soil is porous and well drained the slab is placed directly on the ground. Sometimes tarred felt is placed under the slab of inside floors as an aid in preventing dampness.

All concrete pavements should preferably be located where the drainage is good, so that water will not stand in the sub-base. Where this is not practicable, and especially when the soil is of stiff clay or the pavement is set lower than the surrounding ground, drainage outlets should be installed to carry off water that might collect and cause injury by freezing. Small trenches filled with gravel or cinders, sloping to ground lower than the sub-base, are effective. In addition to the drainage of the site, surface drainage should be provided so water will not stand on the pavement. This is accomplished by pitching the pavement one-eighth to one-fourth of an inch per foot to a trap, gutter, or other outlet.

### TYPES AND THICKNESS OF PAVEMENTS

Pavements for farm use are best if built in one course the full thickness of the slab, using the same mixture of concrete throughout. The two-course type is used chiefly for walks and inside floors where a smooth finish is desirable, and is built with a thick base of concrete and a ¾- to 1-inch top course of mortar.

No concrete slab, especially if exposed to outside conditions, should be less than 4 inches thick. Floors of poultry houses and basements of dwellings, in well-drained locations, are sometimes made 3 inches thick, but a slab of uniform thickness is difficult to get, and unless the concrete is fully 3 inches thick the floor is likely to prove unsatisfactory.

The slab should be 5 or 6 inches thick where large animals, such as farm horses, will walk on it, and 6 inches or more where traffic is heavy. Where traffic is very heavy or the ground insecure, reinforcement consisting of 1/4-inch or larger rods spaced 12 inches on centers in both directions, or woven reinforcement having no. 8 wires every 6 inches, may be necessary.

In two-course work the bases of 4- and 6-inch slabs may be 3 1/4 and 5 1/4 inches. The top course should never be less than three-fourths of an inch thick; sometimes, when subjected to heavy loads, it is made 1 1/2 inches thick.

### FORMS

Usually 2-inch lumber of a width equal to the thickness of the concrete slab is used for pavement forms. Sheet metal or 1/2-inch boards are utilized around curves. Forms are generally set after the sub-base has been placed and should be held rigidly in position by stakes placed close enough together to prevent bulging. The top edges of the forms should be carefully set to conform to the finished grade.

### BLOCKING OFF

For convenience in building and to provide for expansion and contraction, concrete slabs, whether for inside or outside paving, should be laid in blocks. No slab should be larger than 10 feet square for inside floors nor larger than 6 feet for outdoor use. These recommendations regarding blocking off do not apply to road construction nor to supported reinforced floors, as such work is generally done in accordance with special specifications and design.

The separation into blocks can be accomplished in different ways.

The first step is to lay 2-inch scantlings to grade and line along two sides of a number of blocks, the width of a block apart, or along the two sides of a walk. Marks should be made on these side forms, where the cross joints or block divisions are to be located, to facilitate setting the transverse forms and so that grooves in the top course of a two-course pavement can be made exactly over the joints in the base. If the concrete is to be laid continuously, boards are placed between the side forms at the marks with strips of tarred felt against them. Concrete is placed on both sides of the board which is then lifted out, leaving the felt in a vertical position extending across the block and the full depth of the slab. Where alternate blocks are to be formed the cross forms are arranged as shown under Feeding Floors (p. 35), and every other section is concreted. When these blocks have become firm the cross forms are removed and the intervening spaces filled. Strips of tarred felt should separate successively cast blocks.

### EXPANSION JOINTS

Expansion joints consist of spaces one-half to 1 inch wide, extending the full depth of the slab and filled with asphalt, strips of felt made especially for the purpose, or folded strips of tar felt. Generally such joints should be located along abutting buildings, near

trees, at curbs, both ends of curves, around manholes, and 20 to 30 feet apart in straight walks. The importance of properly located expansion joints is not realized until the paving buckles, shears off a manhole, or pushes a light structure or curb out of alinement. A very common error is to omit the expansion joint where an inside floor abuts foundation walls. A ¾-inch joint (fig. 13) should be provided around the perimeter, and when the floor covers a large area there should be several transverse and longitudinal joints one-half inch wide. If the joints are filled with asphalt or a suitable mastic there should be no question regarding sanitation or watertightness.

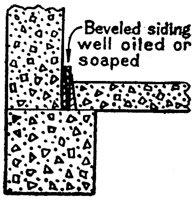


FIGURE 13.—A convenient method of forming expansion joints for floors.

#### MATERIALS

The coarse aggregate for the base should vary in size from one-half to 1½ inches but should not be larger than 1 inch for one-course construction. Coarseness and ability to resist abrasion are two essential qualities of the fine aggregate, especially for the top coat. Sand, 40 percent of which is composed of ⅛- to ¼-inch grains is not too coarse, as considerably less fine aggregate is required for the finish concrete of floors than for that of normal concrete. Where the pavement is to be subjected to heavy trucking, as in some storage buildings, aggregates in the wearing course should have the toughness and hardness possessed by trap, fine-grained granite, and quartzite.

In two-course work, concrete for the base is generally mixed in the proportions of 1:2½:5, though 1:3:6 will give good results when first-class materials are used. The mortar for the top course is usually mixed 1:2. Concrete for one-course pavements is generally a 1:2½:3½ mixture.

Concrete should be mixed to a jellylike consistency, but mortar should be mixed to a stiffness that will require it to be scraped from the bucket or barrow. If made too wet, several trowelings will be necessary to obtain the final finish, in which case the wearing quality of the concrete is impaired.

#### PLACING THE CONCRETE

Just before the concrete is deposited, the ground, or the cinder subbase if used, should be wetted down with water. In one-course construction the concrete, after it is placed, is compacted by tamping until mortar flushes to the surface, and then leveled off with a straight-edge even with the side forms. Where a smooth surface is desired the final floating and grooving is not done until the concrete or mortar has been in place from 1 to 4 hours and has partly set. In two-course construction the concrete base is lightly tamped and leveled off, or screeded, with a template notched over the side forms to the proper depth for the top course. If an excess of water appears on the surface it should be soaked up by burlap bagging or similar material spread for a few minutes over the concrete, because free water in the base course will reduce the strength and durability of the top course. Unless the base is to be left roughened, the top

course must be placed while the base is still plastic, not more than one-half to three-fourths of an hour after the base is laid, and screeded flush with the top of the forms and at the right grade. While some compacting occurs during the screeding, the top course should be further consolidated by floating or rubbing the surface with a wood or cork float to fill up hollows and smooth out the humps left after screeding. Sometimes when further density is desired additional coarse aggregate is scattered over the surface and forced by the float into the mortar topping.

The placing of the top course may be deferred until the base has hardened. In this case the base should be laid as previously described, and while the concrete is still plastic the surface should be scored with a stiff broom and cured for not less than 10 days to permit initial shrinkage due to hardening. Before the topping is placed, the base should be thoroughly cleaned by being scrubbed with clean water and a stiff brush, foreign substances which cannot be removed by scrubbing should be chipped away, and the areas roughened with a pick or cold chisel. Just before the topping is placed, the base should be wetted, but there must be no pools left on the surface. A thin coat of grout should be broomed into the surface of the slab for a short distance ahead of the topping. The wearing course is placed and finished in the same manner as described for laying it on a plastic base.

### FINISHING THE SURFACE

Occasionally the top course is cut through, over the joints in the base, and the surface marked off by small grooves. This is not structurally essential, but improves the appearance of the pavement by breaking the monotony of an otherwise undecorated surface. After the top course has been placed, the location for the grooves is determined by the marks previously made on the side forms and found exactly by running the point of a small trowel through the top course and into the base joint. The trowel is guided by a straightedge and run across the width until a complete cut is made. The four edges of each block are then rounded off with a groover or edging tool. Marks or rough places are erased and the surface given a final finish with a wood float.

A slippery pavement is always undesirable, especially where stock is kept. A rough surface resembling corduroy in appearance offers good foothold and can be easily produced in varying degrees of roughness by sliding a straightedge along the side forms with a sawlike motion and at the same time jigging it up and down a little. This should be done while the concrete is fairly soft. A very satisfactory finish for feeding floors is obtained by roughening the surface with a stiff broom after the concrete has set sufficiently, after all the liquid has disappeared. Sometimes foothold for animals is provided on smooth surfaces by making parallel grooves one-fourth to half an inch deep and about 6 inches apart in two directions with a groover.

A finish of a gritty or sandlike texture that is smooth but not slippery may be obtained by sprinkling a little sharp sand over the surface and lightly rubbing it in with a wooden float used with a

circular motion. A glassy surface is produced with a steel trowel after the concrete has set fairly hard. Experience is necessary in determining the exact time for final troweling and in obtaining various effects produced by the different methods of finishing.

Too much troweling of the surface or troweling too soon after depositing the concrete not only makes the surface slippery but also brings an excess of fine material to the surface. This affects the wearing quality of the pavement and is likely to cause dusting and hair cracks, which, though not detrimental, mar the appearance of the surface. These cracks may also be the result of too much fine sand.

### CURING

Neglect in curing a pavement is a more serious matter than is ordinarily appreciated. Methods of curing are described on page 23. Foot traffic should be kept off the pavement from 2 to 3 days; animals and heavy loads should not be allowed on the paving for about 2 weeks after the concrete has been placed. Paving that has not hardened sufficiently to resist pitting may be protected from rain with a 1-inch layer of sand.

It is not advisable to lay outside pavements in freezing weather; but if they must be laid, the material should be heated and the concrete carefully protected. Manure should never be used to cover newly laid work because it contains acids which react on the green concrete.

### DUSTING

Disintegration of the surface of indoor concrete pavements into fine particles is known as dusting, and invariably is the result of poor workmanship or materials or both. Some of the causes of dusting are: Too fine and soft a sand; too lean a mixture; insufficient mixing; improper consistency; overtroweling when finishing; using dry cement to hasten the drying of the surface.

There are various treatments designed to harden the concrete and reduce dusting. These may be divided into proprietary and home treatments. The success of such treatments depends on the quality of the paving. Hardener treatments may or may not stop dusting.

Two home treatments that have proven very successful and are inexpensive to apply are given below:

Commercial sodium silicate (water glass) usually varies in strength from a 30- to a 40-percent solution. It is very viscous and has to be thinned with water before it will penetrate the floor.

Ordinarily it will be found satisfactory to dilute each gallon of the silicate with 3 gallons of water. The resulting 4 gallons may be expected to cover 200 square feet of floor surface with one coat. The solution should be made up immediately before it is used.

Before the solution is applied the floor surface should be cleaned of all grease spots, dirt, and other foreign matter and thoroughly washed with clear water. To insure the greatest penetration, the floor should be thoroughly dry, especially at the first application; if practicable it is well to allow it to dry for several days after the first scrubbing. The solution may be applied with a mop or hair broom and should be brushed back and forth over the surface for

several minutes to obtain an even penetration. An interval of 24 hours should be allowed for each treatment to harden, after which the surface should be scrubbed with clear water and allowed to dry. Three applications will usually suffice, but if the floor does not then appear to be saturated a fourth will be required.

A solution of aluminum sulphate should be made in a wooden barrel or stoneware vessel. The quantity required may be estimated on the basis of 1 gallon of solution to each 100 square feet of area. For each gallon of water, 2½ pounds of powdered sulphate will be required. The water should be acidulated by adding not more than 1 teaspoonful of commercial sulphuric acid for each gallon. The sulphate does not dissolve readily and has to be stirred occasionally for a period of a few days until the solution is complete.

The floor should be cleaned of grease and dirt and then thoroughly scrubbed. When the surface is entirely dry, a portion of the sulphate solution may be diluted with twice its volume of water and applied with a mop or hair broom. After 24 hours another portion of the original solution, diluted with an equal volume of water, should be applied in the same manner as the first. After another interval of 24 hours there should be a third application, 2 parts of the sulphate solution being used, to 1 part of water. At each application the liquid should be brushed back and forth over the surface for several minutes to obtain a uniform penetration. After the third application has dried the surface should be scrubbed with hot water.

### SPECIAL SURFACE TREATMENTS

Colored surfaces may be had by using various pigments mixed in with the finish mortar. Best results are obtained with machine-mixed materials, but if it is desired to make the colored mortar on the job table 4 will be helpful in obtaining various shades. Test samples should be made and allowed to dry thoroughly to determine the exact quantities needed. All material, including the water, should be accurately measured for each batch.

TABLE 4.—*Pigments used to color concrete floors*

| Color desired | Commercial names of pigments | Quantity of pigment per bag of cement for— | |
|---|---|---|---|
| | | Light shade | Medium shade |
| | | *Pounds* | *Pounds* |
| Gray, blue black, or black | Germantown lampblack | ½ | 1 |
| | Carbon black | ½ | 1 |
| | Black oxide of manganese | 1 | 2 |
| | Mineral black [1] | 1 | 2 |
| Blue | Ultramarine blue | 5 | 9 |
| Brownish red to dull brick red | Red oxide of iron | 5 | 9 |
| Bright red to vermilion | Mineral turkey red | 5 | 9 |
| Red sandstone to purplish red | Indian red | 5 | 9 |
| Brown to reddish brown | Metallic brown (oxide) | 5 | 9 |
| Buff, colonial tint, and yellow | Yellow ocher | 5 | 9 |
| | Yellow oxide | 2 | 4 |
| Green | Chromium oxide | 5 | 9 |
| | Greenish-blue ultramarine | 6 | 10 |

[1] Only first-quality lampblack should be used. Carbon black is of light weight and requires very thorough mixing; black oxide or mineral black is probably most advantageous for general use. To obtain black concrete use 11 pounds of the oxide for each bag of cement.

A concrete floor to be painted should first be made thoroughly clean and dry. The alkalinity should be neutralized by brushing the surface with a solution of 4 pounds of zinc sulphate and 1 gallon of water. After 48 hours, when the surface is dry, the paint may be applied. Paint dealers can supply special concrete paints having an abrasion-resisting pigment, which should be used in accordance with the manufacturer's directions. A farmer mixing his own paint may substitute for one-fourth the usual quantity of raw linseed oil the same amount of raw soybean oil.

Milk-house floors can be effectively protected against the lactic acid in milk products if warm linseed oil is applied after the floors have thoroughly dried out and is worked around with a brush or mop. Thin oil has greater penetration than thick oil. Excess oil should be removed with a squeegee before the oil becomes tacky. A hard floor wax should be applied after this treatment and should be renewed from time to time.

Another treatment for milk-house floors consists of applying a paste compound of 4 parts paraffin, 1 part turpentine, and 16 parts toluol (by weight).[5] Care should be exercised in handling this mixture as it is inflammable. The mixture should be spread on the floor and allowed to penetrate for 24 hours; then it should be driven into the concrete by heat, preferably by using a hot iron, as an open flame creates a fire hazard. The floor should be waxed as recommended in connection with the first method.

### FEEDING FLOORS

A feeding floor should be located convenient to feed and water supplies and should be accessible from pastures, barns, or feed lots. The lee of a building, hill, or woods is desirable, as the stock will be protected from cold winter winds. A southern exposure is best, as the heat of the sun prevents ice and snow from remaining for any great period of time.

Feeding floors are usually 5 inches thick and of the one-course type, the surface being finished by floating as described on page 31. The surface should be pitched or sloped one-eighth to one-fourth inch per foot to allow for drainage. The area will depend on the number and size of troughs to be provided and the kind and number of stock to be fed. Usually 15 square feet is provided for each hog and 40 square feet for each head of cattle.

Consideration should be given to the exact location of drinking troughs, feed racks, fence posts, and other equipment, so that anchorage, connecting pipes, foundations, and drains can be installed before the concrete slab is placed. When the floor is to constitute the bottom of small troughs, the sides of the troughs should be cast at the same time as the floor or before it has set too hard. The trough form should be set in place and leveled as soon as the concrete floor is laid. As the floor is sloped, the top of the trough will be higher at one end or side than at the other unless the bottom of the form is made to conform to the grade of the floor. Foundations for large tanks should be placed before the floor is laid. Anchorage for racks

[5] Paraffin should have a melting point of 150° F. Toluol is a coal-tar product available from most druggists for about 20 cents per gallon.

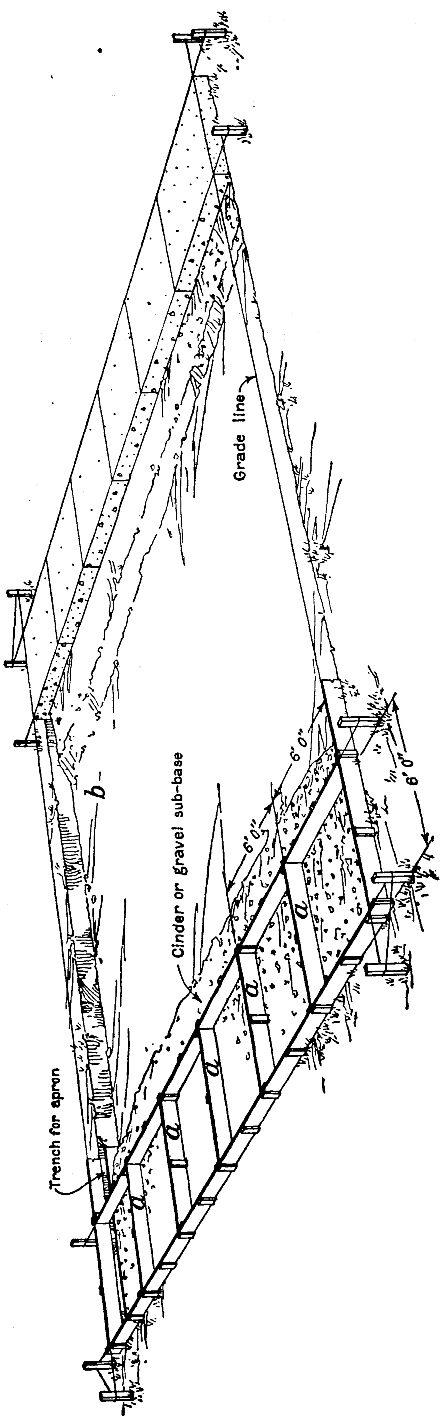


FIGURE 14.—Lay-out of forms for feeding floor: *a*, Transverse scantlings; *b*, bottom of excavation.

may consist of dowels or straps set half their length in the floor. Post holes for removable fences may be formed by inserting sleeves of pipe or wood plugs with a diameter a trifle larger than that of the posts.

As the floor should be formed of blocks, it will be best to start work at the lowest point, so that rain will not run from hardened onto newly placed concrete. The forms may be arranged as in figure 14.

Forms of two or more alternate strips may be laid out at one time, depending on the quantity of concrete to be placed in a day. When the first blocks have hardened sufficiently to be self-sustaining, the transverse scantlings (*a*) may be removed and the intermediate blocks cast. The same operation should be repeated for each strip.

Frequently, because of the topography or to save excavation, the concrete slab of a feeding floor is laid above the grade of the surrounding ground, and when this is done an apron or curtain wall should be built under the sides of the floor. An apron (fig. 15) is advisable under all feeding floors to prevent undermining by hogs, and raveling due to wash and to eliminate harborage for rats. The apron should be about 6 inches thick and extend deep enough to guard against erosion and undermining and be below frost, 18 inches below the ground being usually sufficient. The trenches for the curb may

be dug after the forms are set and be filled at the same time the slab is poured.

Gutters and curbs should be provided around the sides of the floor. A curb 4 to 6 inches high above the grade of the floor serves to retain feed upon the floor. Forms for such a curb, which may be cast separately or with an apron, are shown in figure 15.

## CURBS

Frequently curbs are used in connection with the different types of paving. Curbs may be of either two-course or one-course construction, but the tendency is toward one-course work; that is, the same mixture throughout. A good finish can be obtained by properly tamping and spading the concrete, removing the forms as soon as practicable, and troweling the surface.

The plain curb is usually built 6 to 8 inches thick at the top, 8 to 10 inches thick at the bottom, and 18 to 24 inches deep. Figure 16, *A*, shows how the forms are constructed and braced. Figure 16, *B*, shows the construction of forms for a combined curb and gutter. The curb should be built in sections not over 10 feet in length, and expansion joints should be provided 25 feet apart. Generally a gutter is formed at the intersection of a curb with the paving, and care should be taken to pitch the gutter to outlets or drains for removing surface water. Plain curbs of reinforced concrete may be precast in sections 4 to 8 feet long. They are usually 4 to 8 inches thick and 18 to 24 inches high. The reinforcement may consist of longitudinal rods one-fourth of an inch in diameter, spaced 6 inches apart. The rods should be tied together with wires spaced 6 to 8 inches apart. A piece of heavy woven-wire fencing 1 inch less in length and height than the curb section makes satisfactory reinforcement; the wires should not be less than no. 10 gage.

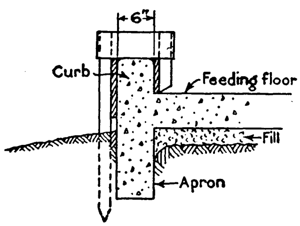


FIGURE 15.—Curb and apron.

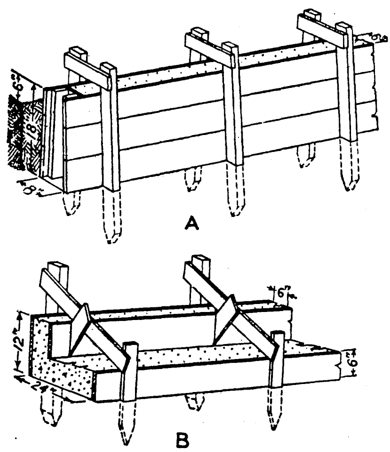


FIGURE 16.—*A*, Plain curb; *B*, curb with gutter.

## WALKS

The conventional type of concrete walk is a strip of paving $1\frac{1}{2}$ to 3 feet or more wide and is built in the same manner as feeding floors. To prevent water standing on the surface, the walk may be built a little higher than the surrounding ground and crowned or made with

one side a trifle lower than the other. Water from downspouts should be diverted by tile drains or properly sloped gutters so that it will not flow across the surface and become an ice hazard in winter. Figure 17 illustrates the usual method of setting up the forms. When used only as a walk, a slab 4 inches thick is sufficient and is generally laid in one course. A smooth, gritty surface finish is desirable, but the roughness of the surface should be increased with an increase in the grade. When the slope is greater than 20 percent (1 foot vertical to 5 feet horizontal) steps should be used to obtain flatter grades.

The flagstone or stepping-stone type of walk is greatly esteemed for use in gardens or across lawns. These are merely concrete slabs 4 inches thick and may be precast or cast in place. Considerable trouble may be avoided and the use of forms eliminated by casting

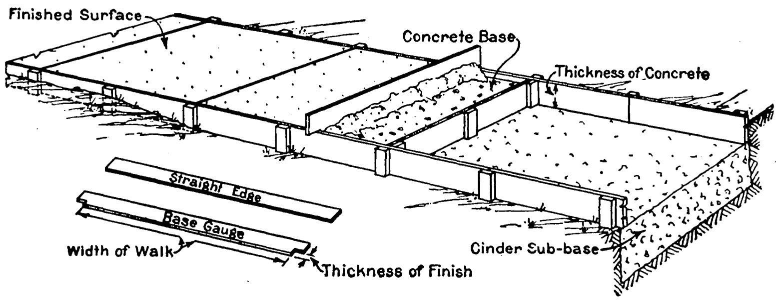


FIGURE 17.—Walk forms.

the stepping stones in place, especially if they are to be irregular in shape. All that is necessary is to remove the sod and excavate the soil 2 or 4 inches deeper than the thickness of the slab so that the hole will have the desired shape, the edges being vertical. A sand base, as described below, is then rammed in place to provide drainage; the concrete is then placed and troweled. Other surface finishes described for pavements, including the use of colored pigments, can be employed. No trouble should be experienced in building forms for precast slabs, which consist of a rectangular frame divided by crosspieces or strips and set on a level surface. Different patterns can be made by varying the arrangement of the strips which divide the blocks. The division for irregular-shaped blocks can be made of plastic clay. The blocks should not be made too large to handle; one 12 by 18 by 4 inches will weigh about 75 pounds. Before such slabs are laid, a trench 2 to 4 inches deeper than the thickness of the slab should be excavated. Sand is then rammed in the trench and screeded to 4 inches below the finished surface, so as to provide drainage and a smooth base for bedding the stones. The joints are then filled with sand or loam. Where the earth is porous and rather free of large gravel a smooth bed may be made without sand.

## STEPS

The vertical height or face of a step is called the "riser", and the horizontal surface the "tread." Concrete steps are built by casting

the risers and treads on an inclined slab, the thickness of which depends on the span or method of support.

When the slab rests on solid earth or on an earth fill between concrete or other masonry walls and there are but three or four steps from 3 to 4 feet wide, a 4-inch slab is sufficient; but for wider and

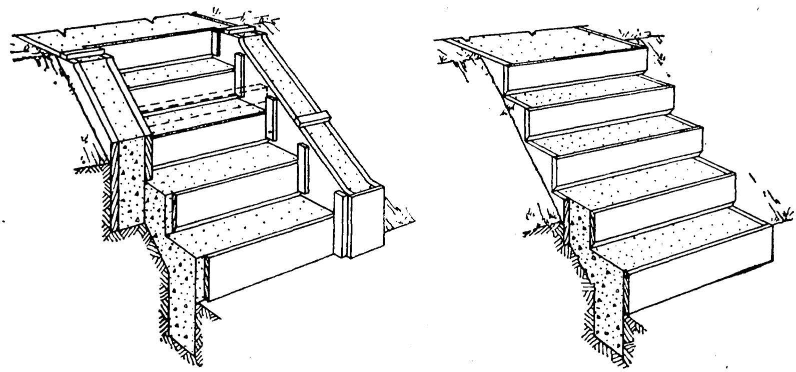

FIGURE 18.—Steps supported on earth. Parts of forms are cut away to show construction.

longer flights the slab should be 6 inches or more in thickness. Two arrangements of forms are illustrated in figure 18. Steps that do not rest on solid earth or fill must be self-supporting and hence must be reinforced. The longitudinal reinforcement given in table 5 should be placed lengthwise, from top to bottom, 1 inch up from the

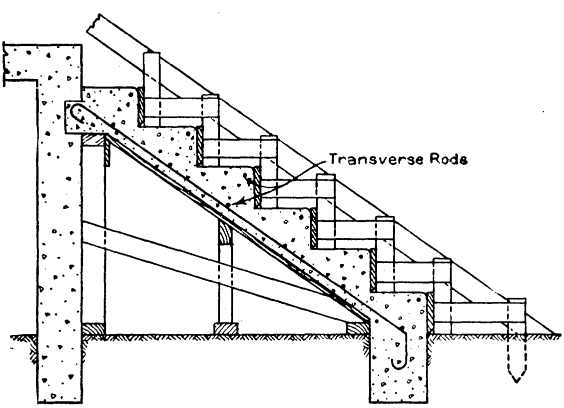


FIGURE 19.—Forms for self-supporting steps.

under side of the slab. It is advisable to place rods of small diameter extending across the width of the slab, 12 to 24 inches apart, and these rods should be securely wired to the larger rods at the intersections. It is very important that self-supporting steps have a firm support at the head, such as the slab of a concrete porch or masonry wall; the foot may be secured as in figure 19.

TABLE 5.—*Reinforcement for concrete step slabs*

| Slab dimensions | | Round reinforcing rods | | | |
|---|---|---|---|---|---|
| | | Longitudinal | | Transverse | |
| Length | Thickness | Diameter | Spacing | Diameter | Spacing |
| *Feet* | *Inches* | *Inch* | *Inches* | *Inch* | *Inches* |
| 2 to 3 | 4 | 1/4 | 10 | 1/4 | 12–18 |
| 3 to 4 | 4 | 1/4 | 5½ | 1/4 | 12–18 |
| 4 to 5 | 5 | 1/4 | 4½ | 1/4 | 18–24 |
| 5 to 6 | 5 | 3/8 | 7 | 1/4 | 18–24 |
| 6 to 7 | 6 | 3/8 | 6 | 1/4 | 18–24 |
| 7 to 8 | 6 | 3/8 | 4 | 1/4 | 18–24 |
| 8 to 9 | 7 | 1/2 | 7 | 1/4 | 18–24 |

The concrete should be mixed in the proportions of 1:2½:3½ unless a ¾-inch top course of mortar is to be applied, when a 1:3:5 mixture is satisfactory for supported slabs. The entire slab should be poured at one time, and the concrete should be mixed fairly dry so that when placed it will not be forced over the riser forms at the bottom of the steps by the pressure from above. The surface of the treads should be finished as soon as the base concrete is placed. A rough sand finish is preferable, as it offers a good foothold.

The riser should bear a certain relation to the width of the tread and at the same time should be between 6 and 8 inches in height. Low risers and broad treads are generally preferable for outside steps. Risers 6½ to 7½ inches high, with properly proportioned treads, permit of ascent with least effort and are most commonly used. High risers and narrow treads are used only where the horizontal distance is limited. A desirable formula is that twice the height of the riser plus the width of the tread should equal 25. Although not necessary, it is a good plan to project the tread one-half to three-quarter inch beyond the riser. This may be accomplished in the manner shown in figure 20. The treads should have a pitch of from one thirty-second to one-sixteenth of an inch toward the front, in order to shed water. Drains or gutters should be provided at the top to prevent water from flowing down the steps.

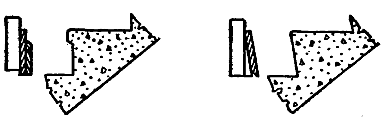

FIGURE 20.—Types of risers, with forms

DRIVEWAYS

Three types of driveways are illustrated in figure 21. The choice of which to build depends on personal preference and the amount of traffic expected. For frequent and heavy traffic a pavement covering the whole drive is best. Narrow parallel strips give good service for occasional use, while curbs as shown in figure 21, *B*, prevent vehicles running off and cutting up the lawn. Gravel is sometimes placed between the strips when it is difficult to keep the sod in good condition. A 6-inch one-course slab with a smooth gritty surface is recommended. Care must be taken to consolidate the earth under the pavement to prevent settlement. The necessity for a sub-base and drainage depends on the kind of soil at the site.

## CULVERTS

Where small ditches cross a road and must be covered, it is very difficult to arrange the forms so as to permit easy removal. Figure 22 suggests the use of a sand fill and a wooden trough supported on 1-inch blocks 4 to 5 feet apart for the form. Water flushed through the trough scours out the sand so that the trough is easily removed and a clear channel secured. The slab should be 6 inches thick, reinforced with ½-inch rods spaced 6 inches on centers for spans up to 5 feet and ordinary farm loads. Greater spans or spans for heavy loads should not be attempted without technical advice.

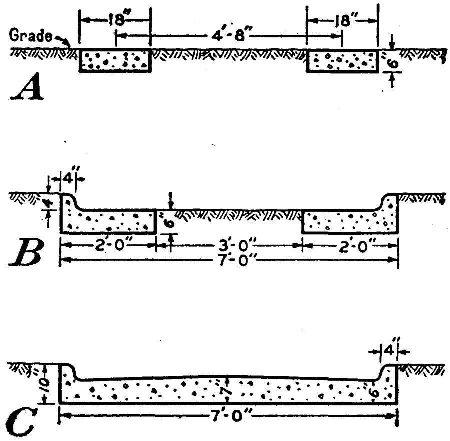


FIGURE 21.—Types of driveways: *A*, Plain strip; *B*, curbed strip; *C*, full paved.

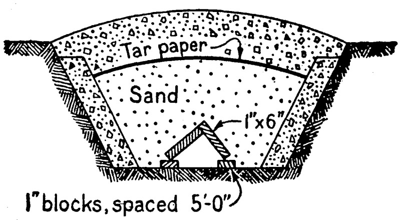


FIGURE 22.—Sand form for culvert.

## BARN FLOORS

The concrete for barn floors should be mixed and handled as for the construction of walks and feeding floors. There should be a sub-base of porous material under the entire floor if the soil is water retentive. A sub-base directly under all concrete stall floors is advisable in order to break capillary attraction and secure a measure of insulation. A semirough or float finish is desirable, as it will not become slippery; see page 32. Figure 23 shows a typical cow stall, the dimensions of which vary with the breed of cattle, in accordance with table 6.

TABLE 6.—*Suggested dimensions for cow stalls* [1]

| Breed | Width (*W*) | | | | Length (*L*) Small | | Medium | | Large | |
|---|---|---|---|---|---|---|---|---|---|---|
| | *Ft.* | *In.* | *Ft.* | *In.* | *Ft.* | *In.* | *Ft.* | *In.* | *Ft.* | *In.* |
| Holstein | 3 | 6 to | 4 | 0 | 4 | 10 | 5 | 2 | 5 | 8 |
| Shorthorn | 3 | 6 to | 4 | 0 | 4 | 8 | 5 | 0 | 5 | 6 |
| Ayrshire | 3 | 6 to | 3 | 8 | 4 | 6 | 5 | 0 | 5 | 6 |
| Guernsey | 3 | 4 to | 3 | 6 | 4 | 6 | 4 | 10 | 5 | 4 |
| Jersey | 3 | 4 to | 3 | 6 | 4 | 4 | 4 | 8 | 5 | 0 |
| Heifers | 2 | 9 to | 3 | 2 | 3 | 8 | 3 | 10 | 4 | 2 |

[1] Dimension *S* (see fig. 23) should be 3 feet 6 inches for cows and 3 feet for heifers and young stock. Stalls for cows in milk should be not less than 3 feet 4 inches wide. In determining the length of stalls the largest and the smallest cows of the herd should be measured. The longest stall should be laid out at one end of the row and the shortest at the other. The gutter should form a straight line between the two, thus providing stalls of various lengths. The horizontal distance between shoulder point and tail head plus 6 inches is approximately the proper length of stall from stanchion line to edge of gutter.

The stanchion curb should be made first, but before the concrete is placed all plumbing fittings, stanchion sleeves, uprights, and anchor bolts should be set accurately in the forms in accordance with

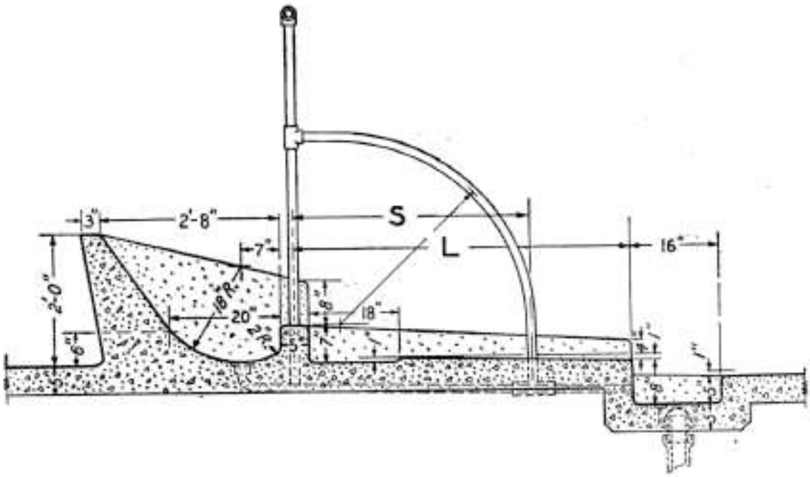


FIGURE 23.—Floor for cow stalls.

the manufacturer's directions. Figure 24 suggests a convenient arrangement of forms and a method of holding the stanchion upright

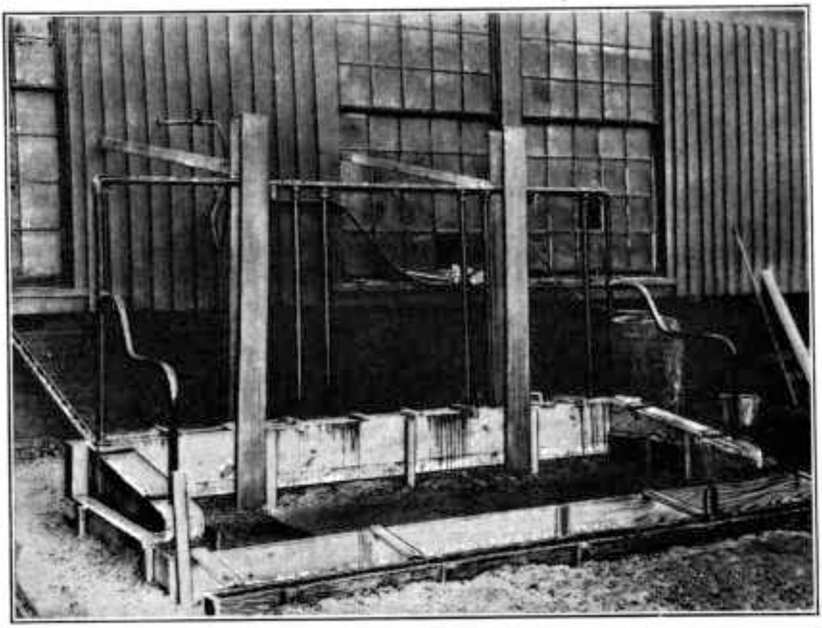

FIGURE 24.—Placing curb and stanchions.

in place until the concrete hardens. The successive steps in building a cow-stable floor are shown in figure 25. Figure 26 shows the method of forming the high-front manger shown in figure 23.

Templates made of wood or metal templates conforming to standard manger divisions may be purchased from barn-equipment dealers.

Where funds were extremely limited and rock plentiful, farmers have built barn floors successively by laying a rock foundation to

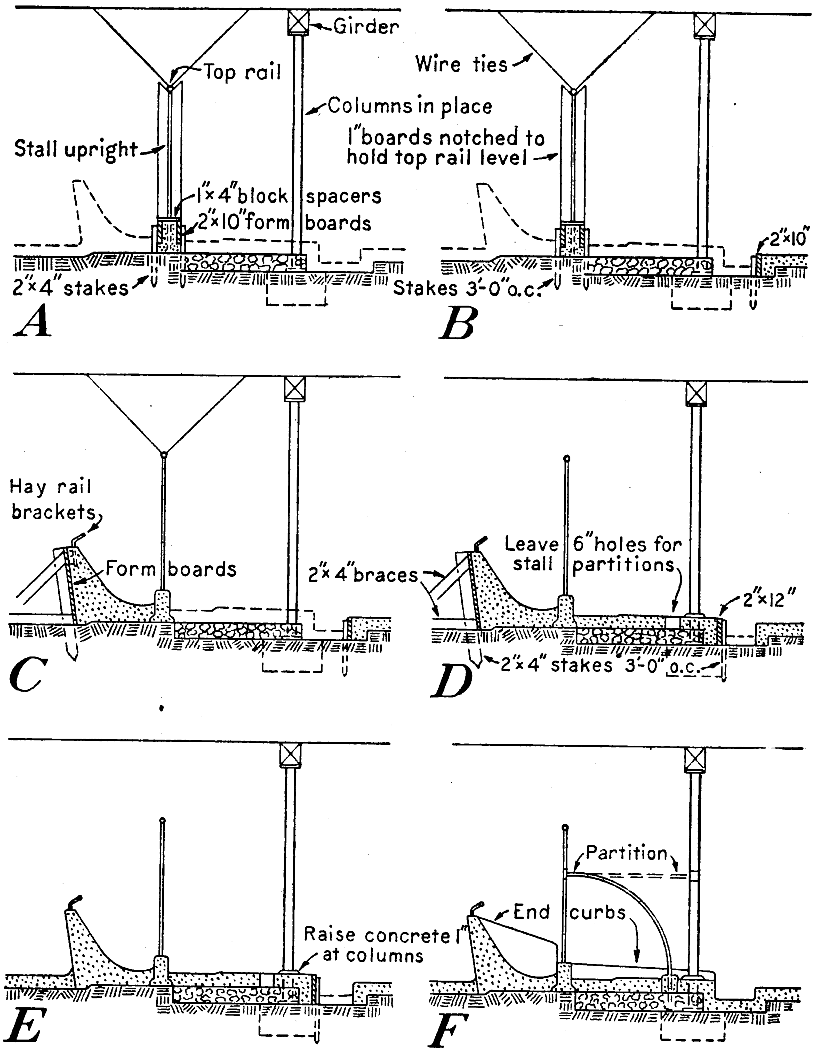


FIGURE 25.—Steps in building a concrete floor in a cow barn: *A*, Stanchion curb is built first, with all stanchion anchors set; *B*, litter alley is built while stanchion curb hardens; *C*, curb forms are removed, and manger is built with hay-rail brackets set; *D*, standing platform is built while manger hardens; *E*, manger forms are removed and feed alley is built; *F*, gutter and end curbs are built, and stall partitions are grouted in.

within 1½ or 2 inches of the finished surface and applying a thin layer of concrete just prior to placing the last inch of wearing surface. This expedient involves a greater amount of labor than for all-concrete floors but is economical of cement and should be considered if wages are not paid for labor.

## TANKS AND TROUGHS

To insure tightness in a tank or other water-holding structure, the concrete should be mixed and cured as already described (p. 27). As early as practicable the forms should be removed and the exposed surfaces well brushed with a creamy mixture of cement and water to fill the pores.

The inside walls of shallow tanks, the contents of which may be subject to freezing, should have a slope of about 1 inch per foot of

FIGURE 26.—Forming high-front manger.

height so that ice may rise and have less tendency to burst the walls. Large tanks are generally built without this slope, since large quantities of water are not so likely to freeze solid.


FIGURE 27.—Shallow footing for tanks.

Foundations of tanks, especially of large ones should extend below frost line to prevent damage from heaving. A footing such as that shown in figure 27 is sometimes used in well-drained soils where deep freezing does not occur. Where frost action is likely or the drainage is poor, a subbase, as described on page 29, should be placed under the structure. The supporting soil should be all of the same bearing power to permit of uniform settlement; that is, the foundation should not rest partly on rock or any unyielding soil and partly on soft soil.

### REINFORCEMENT

The reinforcement specified herein for each type of trough or tank should be placed in the position indicated; if a change is made without carefully considering whether the values substituted are equivalent, leakage or failure may result.

Rod reinforcement for floors or bottoms of tanks should be placed in two layers at right angles and 2 inches above the bottom of the slab. In small tanks these rods may be bent in the form of a U, so as to serve as continuous reinforcement for both bottom and walls. When this requires too long a rod the vertical wall rods should be bent to lap over the bottom reinforcement from 18 to 30 inches (fig. 28).

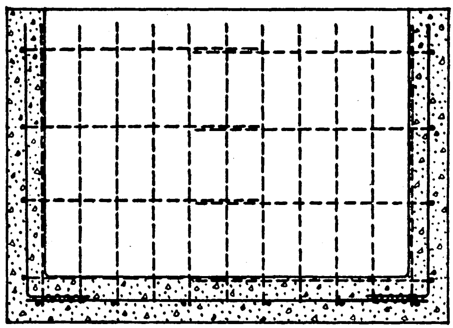

FIGURE 28.—Use of L-shaped reinforcing rods and location of splices.

Horizontal rods should be placed around the outside of and wired to the vertical rods. In round tanks the spacings between the horizontal rods should increase gradually from the bottom to the top. In small watering tanks the wall reinforcement should be placed about 1 inch from the outer face. In large tanks the vertical reinforcement should be placed near the inner surface, to resist the outward pressure of the water. Large square tanks below ground need double reinforcing, one set of rods near the inner surface and another near the outer surface. The reinforcement for circular tanks either above or below ground should be placed as one set, in the center of the wall. When it is impracticable to obtain rods of sufficient length to extend around the perimeter or girth, shorter rods may be spliced or hooked together, the splices or hooks being located in the middle of the sides and never at the corners of rectangular structures. The rods may be bent in the form of a U or an L, depending on their length and the dimensions of the tank (fig. 28).

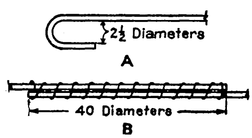


FIGURE 29.—Joining reinforcement: *A*, Hook; *B*, splice.

A hook, as illustrated in figure 29, *A*, can be easily made by slipping a pipe over one end of the rod and using it as a lever. A splice is made by lapping the plain ends of the rods at least 40 diameters and wrapping them securely with wire (fig. 29, *B*); baling wire is satisfactory for this purpose. Forty diameters is equal to 10 inches for ¼-inch rods, 15 inches for ⅜-inch rods, 20 inches for ½-inch rods, 25 inches for ⅝-inch rods, and 30 inches for ¾-inch rods. Hog fencing of no. 9 or 10 gage wires may be used for reinforcement in the floors of small tanks. Poultry wire of 1-inch mesh and 19 gage or heavier will serve for reinforcing small feeding troughs but should not be used for water tanks.

### FIXTURES

Water inlet and outlet pipes should be laid before the concrete floor of the tank is poured. The water level in small tanks can be regulated by screwing a vertical length of pipe into the outlet to serve as an overflow. All exposed metal pipes and fittings should be galvanized. They should also be protected from freezing. A shut-off valve located below freezing depth is advisable on all supplies, so that water need not be wasted should the pipe freeze.

A pavement around a drinking trough is desirable, because it prevents mudholes and protects the foundation of the tank by keeping water away from it. An expansion joint should be made between the tank and paving, so that any settlement or expansion of one will not affect the other.

### WATER-STORAGE TANKS

The size of a water-storage tank should be determined from the daily consumption, the rate of supply, and the length of time it may be necessary to store water. A tank should hold sufficient for from 2 to 4 days, and more if the pump is operated by a windmill. Where a large quantity of water is to be stored for a long period, tanks are not practicable on account of the cost; reservoirs or basins are generally used for this purpose. For estimating water requirements, the following allowances are suggested:

| *Use of water* | *Reasonable quantities (gallons)* |
|---|---|
| Cooking and washing only—no bathroom | 7 to 15 per person per day. |
| All domestic uses in modern home with full plumbing | 20 to 30 per person per day. |
| Tub bath | 8 to 20 per use. |
| Shower bath | 15 to 30 per use. |
| Flushing toilet | 3 to 6 per use. |
| Lavatory | ½ to 1 per use. |
| Family laundry, 5 persons | 30 to 60 per wash. |
| Outdoor sprinkling or washing with ¾-inch garden hose | 120 to 300 per hour. |
| Horse, mule, or cow, for drinking | 10 to 15 per animal per day. |
| Sheep or hog for drinking | 1 to 2 per animal per day. |
| Washing and flushing dairy stable to meet health-department requirements | 15 to 25 per cow per day. |
| Schools | 3 to 15 (average 7) per child per day. |

A method of building forms for large rectangular tanks is illustrated in figure 30. The posts or studs of the inside form are tapered 4 inches at the bottom and are permitted to extend into the floor slab. They can be supported 2 inches or more from the ground by placing bricks or stones under the ends. The taper permits the studs to be withdrawn easily after the concrete floor has hardened. When the studs are removed the holes they leave should be filled with 1:2 mortar. The vertical wall rods should be bent and wired to the floor reinforcement as shown, and held in position temporarily by nails driven under the top hook and into the side form or else by running a horizontal rod under the top hooks and securing it by wires to cleats supported on top of the forms.

In table 7 is given the thickness of concrete, reinforcement, and capacity of tanks of various depths. The area of a rectagular tank does not influence the thickness of walls or the amount of rein-

forcement as much as does the depth of the water; therefore the data of the table may be used for tanks of almost any horizontal dimensions. However, it is advisable to limit the length of the longest side to 16 feet, especially in tanks over 4 feet deep, otherwise expansion or contraction cracks may occur in the walls unless special provision is made.

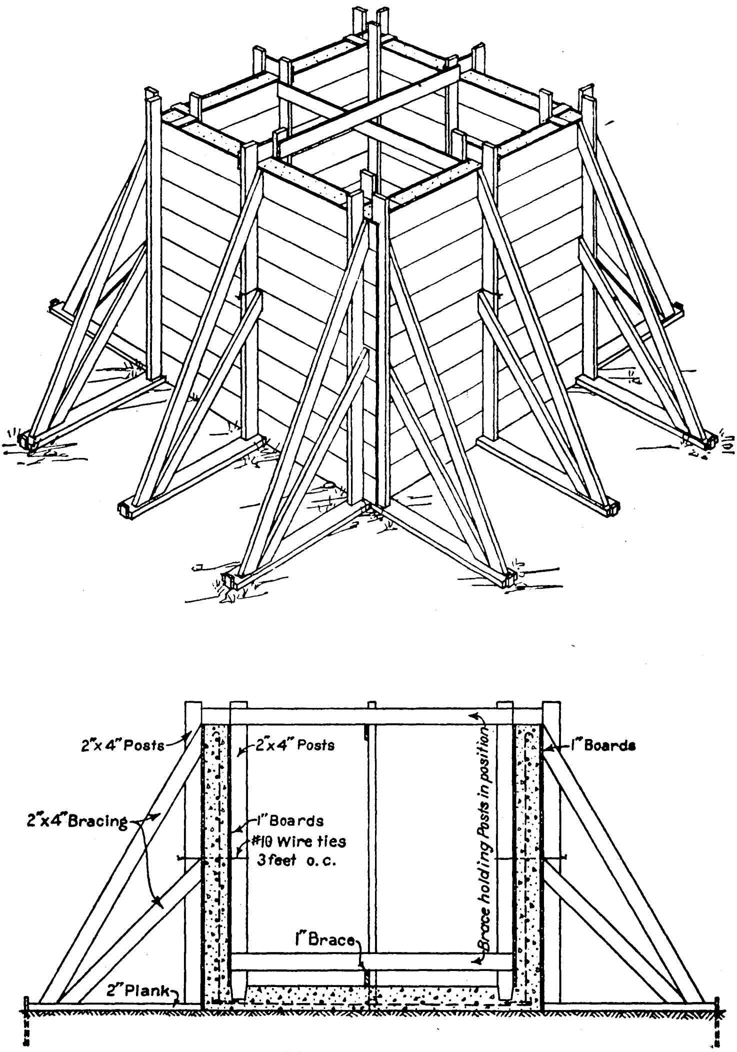


FIGURE 30.—Form for large tank.

Tanks of large capacity are usually made circular because less material is required than in rectangular tanks of the same capacity. Table 8 indicates the thickness and reinforcement of concrete required for round tanks of different sizes. The spacing of the horizontal rods should be increased gradually from the close bottom spacing to the wide top spacing shown. Circular forms are usually

TABLE 7.—*Construction of uncovered rectangular or square tanks in which smooth round reinforcing rods are used*

| Depth of tank | Capacity per square foot of floor | Walls | | | | Floors | |
|---|---|---|---|---|---|---|---|
| | | Thickness | Diameter of reinforcing rods | Spacing of reinforcement | | Thickness | Spacing of reinforcing rods[1] |
| | | | | Vertical rods | Horizontal rods | | |
| *Feet* | *Gallons* | *Inches* | *Inch* | *Inches* | *Inches* | *Inches* | *Inches* |
| 3 | 22½ | 5 | ⅜ | 6 | 8 | 6 | 6 |
| 4 | 30 | 5 | ⅜ | 6 | 8 | 6 | 6 |
| 5 | 37½ | 6 | ½ | 5½ | 12 | 6 | 11 |
| 6 | 45 | 7 | ½ | 4½ | 12 | 6 | 9 |
| 7 | 52½ | 8 | ⅝ | 5 | 12 | 6 | 10 |
| 8 | 60 | 10 | ¾ | 5½ | 16 | 6 | 11 |
| 9 | 67½ | 11 | ¾ | 5 | 16 | 8 | 10 |
| 10 | 75 | 12 | ¾ | 4 | 14 | 8 | 8 |

[1] The floor rods should be placed in 2 layers at right angles to each other, each layer being spaced as indicated. Wall rods should be located as indicated on p. 45.

TABLE 8.—*Reinforcement for circular tanks, using smooth round rods*[1]

| Size of tank | | | Thickness of walls and floors | Reinforcement of walls | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | Horizontal rods | | | Vertical rods | |
| Diameter, inside | Depth | Capacity (approximate) | | Diameter | Spacing | | Diameter | Spacing |
| | | | | | Bottom | Top | | |
| *Feet* | *Feet* | *Gallons* | *Inches* | *Inch* | *Inches* | *Inches* | *Inch* | *Inches* |
| 6 | 3 | 630 | 6 | ⅜ | 7½ | 7½ | ⅜ | 36 |
| 6 | 4 | 840 | 6 | ⅜ | 7½ | 7½ | ⅜ | 36 |
| 6 | 6 | 1, 260 | 6 | ⅜ | 7½ | 7½ | ⅜ | 36 |
| 8 | 3 | 1, 120 | 6 | ⅜ | 7½ | 7½ | ⅜ | 36 |
| 8 | 4 | 1, 500 | 6 | ⅜ | 7½ | 7½ | ⅜ | 36 |
| 8 | 6 | 2, 250 | 6 | ⅜ | 7½ | 7½ | ⅜ | 36 |
| 8 | 8 | 3, 000 | 6 | ⅜ | 7½ | 7½ | ⅜ | 36 |
| 10 | 3 | 1, 760 | 6 | ⅜ | 7½ | 7½ | ⅜ | 36 |
| 10 | 4 | 2, 350 | 6 | ⅜ | 7½ | 7½ | ⅜ | 36 |
| 10 | 6 | 3, 520 | 6 | ⅜ | 7½ | 7½ | ⅜ | 36 |
| 10 | 8 | 4, 700 | 6 | ⅜ | 5 | 7½ | ⅜ | 30 |
| 10 | 10 | 5, 870 | 8 | ½ | 7½ | 10 | ⅜ | 30 |
| 12 | 4 | 3, 380 | 6 | ⅜ | 7½ | 7½ | ⅜ | 36 |
| 12 | 6 | 5, 070 | 6 | ⅜ | 7½ | 15 | ⅜ | 30 |
| 12 | 8 | 6, 760 | 6 | ½ | 7½ | 15 | ⅜ | 30 |
| 12 | 10 | 8, 450 | 8 | ½ | 6½ | 10 | ⅜ | 30 |
| 12 | 12 | 10, 150 | 10 | ½ | 5 | 8 | ⅜ | 30 |
| 14 | 4 | 4, 600 | 6 | ⅜ | 7½ | 7½ | ⅜ | 36 |
| 14 | 6 | 6, 900 | 6 | ⅜ | 5 | 7½ | ⅜ | 36 |
| 14 | 8 | 9, 210 | 6 | ½ | 7 | 15 | ⅜ | 30 |
| 14 | 10 | 11, 510 | 8 | ½ | 5½ | 10 | ⅜ | 30 |
| 14 | 12 | 13, 810 | 10 | ⅝ | 7 | 12 | ⅜ | 30 |
| 14 | 14 | 16, 120 | 12 | ⅝ | 6 | 10 | ⅜ | 30 |
| 16 | 4 | 6, 010 | 6 | ⅜ | 6½ | 7½ | ⅜ | 36 |
| 18 | 4 | 7, 610 | 6 | ½ | 10 | 15 | ⅜ | 36 |
| 20 | 4 | 9, 400 | 6 | ½ | 9 | 15 | ⅜ | 36 |

[1] Floors, which should rest on firm soil, may be reinforced with rods of the same size as the wall rods, and spaced, as shown for the top wall rods, in 2 layers at right angles to each other. In smaller tanks 4-inch concrete floors reinforced with woven wire are sufficient.

made in bands or cylinders 2½ to 4 feet high and are raised as the work progresses as in silo construction. The forms, which are really silo forms, may be made one-fourth, one-half, or the full height of the tank, but the supporting rings should not be more than 2½ to 3 feet apart and should be closer if the depth of concrete to be poured

in one operation is in excess of 3 feet. For farm work, a form 3 feet high is advisable as there is less likelihood of the form bursting because of too great depth of wet concrete and as the concrete can be spaded more easily and with greater assurance of eliminating the spaces. Moreover, the mixing and placing of the quantity of concrete required to fill a form of this depth and from 10 to 16 feet in diameter constitutes an average day's work. A form 30 inches high is preferable when the diameter of the tank is much greater than 16 feet.

Above-ground circular tanks of the sizes specified in table 8 may be covered with reinforced concrete slabs such as those described for underground tanks.

### UNDERGROUND TANKS

The method of building underground rectangular tanks as deep as 7 feet 6 inches and from 10 to 14 feet square is shown in figure 31; deeper and larger tanks should not be attempted without technical

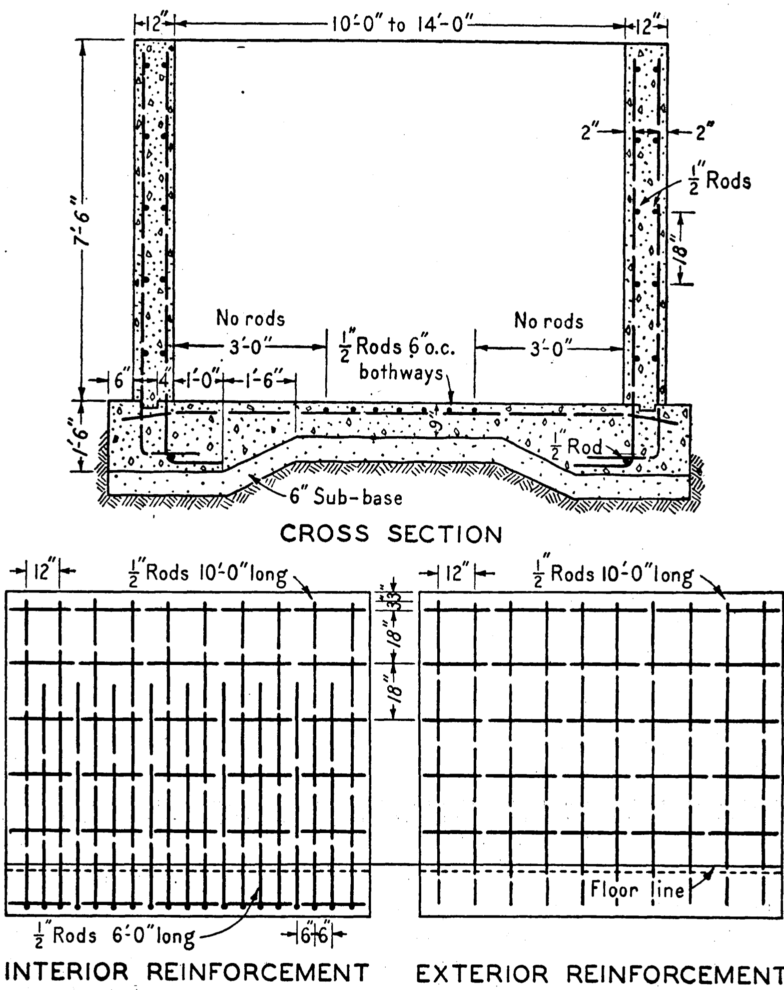


FIGURE 31.—Method of building underground rectangular tanks.

advice. Rectangular tanks below the ground must have two rows of reinforcement in the walls. Round tanks, not over 7 feet 6 inches deep, constructed as indicated in table 8, may be built also below the ground surface. Both rectangular and round tanks may be covered with slabs such as those specified in table 9. Unless the soil is soft, a sub-base of compacted cinders, gravel, or other porous material under the floor of the tank will not be necessary.

TABLE 9.—*Reinforcement for underground tank covers* [1]

| Span (clear width) | No earth on cover | | | 1 foot of earth on cover | | | 2 feet of earth on cover | | |
|---|---|---|---|---|---|---|---|---|---|
| | Slab thickness | Rod diameter | Rod spacing | Slab thickness | Rod diameter | Rod spacing | Slab thickness | Rod diameter | Rod spacing |
| *Feet* | *Inches* | *Inch* | *Inches* | *Inches* | *Inch* | *Inches* | *Inches* | *Inch* | *Inches* |
| 4 | 4 | ¼ | 6 | 4 | ⅜ | 9 | 4 | 8/8 | 6 |
| 6 | 4 | ⅜ | 7 | 4 | ½ | 8 | 4½ | ½ | 6 |
| 8 | 4 | ½ | 7 | 5 | ½ | 6 | 6 | ½ | 5 |
| 10 | 5 | ½ | 6 | 6 | ⅝ | 7 | 7 | ⅝ | 6 |
| 12 | 6 | ½ | 5 | 7 | ⅝ | 5½ | -------- | -------- | -------- |
| 14 | 7 | ⅝ | 6 | -------- | -------- | -------- | -------- | -------- | -------- |

1 The rods indicated in this table should be placed in 1 layer 1 inch above the bottom of the slab, and extend across the shorter dimension. ½-inch rods spaced 12 to 18 inches on centers should extend longitudinally on top of the bottom rods, and be wired to them. All rods should extend over the walls, and it is advisable to make a hook on each end of each rod, and to extend the outside wall rods 2 feet above the walls so they may be bent down and wired to the roof reinforcement. For round tanks, the spacing should be alike in both directions; at the center of the cover it should be as shown in the table, but may be increased somewhat toward the edges.

When tanks are covered, a manhole about 1½ by 2 feet should be provided to permit the removal of forms and cleaning. The forms should be so designed that they can be taken apart and the lumber removed through the manhole. Figure 32 shows how forms for rectangular tanks may be built.

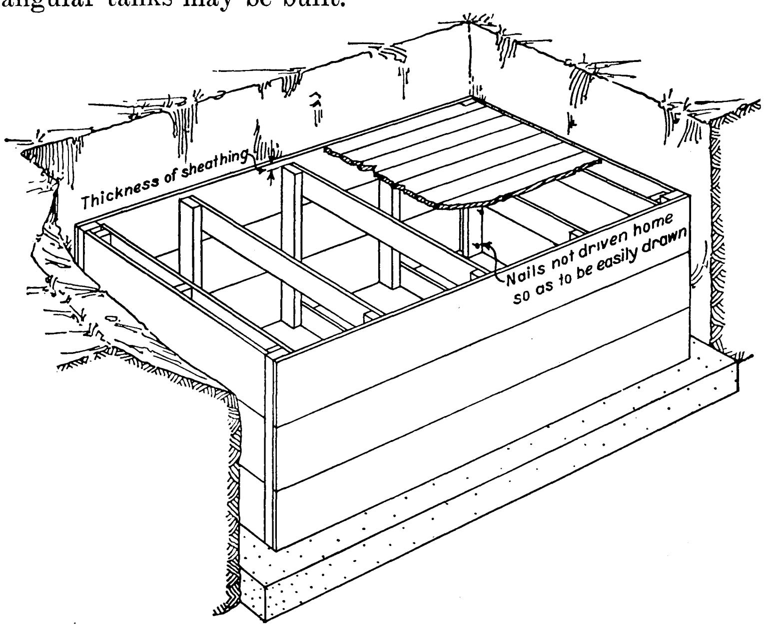


FIGURE 32.—Form for underground tank.

The cover slabs specified in table 8 are not sufficiently strong to permit being driven over; hence the tanks should be located where this will not occur. When the span is greater than 14 feet, beam and column construction, which is beyond the scope of this bulletin, is recommended.

#### TANKS FOR CIDER OR VINEGAR

If well made, concrete tanks are suitable for storing many liquids if the surfaces are protected against chemical action. If the inside surfaces are treated with paraffin, cider and vinegar may be stored in them. Paraffin may be applied either cold or hot. In the cold method, the paraffin is dissolved in a volatile carrier like naphtha until a saturated solution is obtained. Four pounds of paraffin dissolved in one-half gallon of gasoline or naphtha will make 1 gallon of solution. This solution is applied like paint to the surface

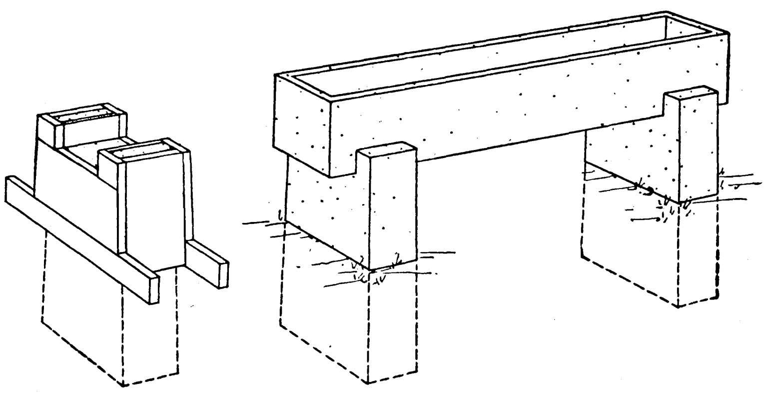

FIGURE 33.—Small drinking trough on piers, and pier form.

of the concrete, which it penetrates according to the dryness, porosity, and temperature. One gallon will cover about 200 square feet of surface. Good ventilation should be provided in the tank when this solution is being applied, and special precaution should be taken to prevent fire or explosion, as naphtha is very inflammable. Paraffin may be applied in melted form. It requires 6½ pounds of solid paraffin to make 1 gallon when melted. One gallon will cover about 250 square feet of surface. The work should be done on a warm day, and the concrete should be warmed with a blowtorch or by other artificial means.

#### WATERING TROUGHS

An oblong trough is preferable for stock watering in that it permits more stock to be watered at one time than does a square trough of the same area. Shallow troughs set on piers (fig. 33) require less concrete. The height of the piers will depend on local conditions, and they should be spaced not more than 6 feet apart unless extra reinforcement is used.

The larger rectangular drinking troughs range from 2 to 3 feet in width, and the length is determined by the number and kind of

stock to be watered at one time. The depth ranges from 1 foot to 2 feet 6 inches. As these troughs are relatively small and built directly upon the ground, they do not require very much reenforcement. Heavy woven wire is sometimes used, but 1/4-inch round rods spaced 6 inches apart in both directions are better, as it is difficult to place the wire mesh accurately.

Since it is always desirable to pour the troughs as a unit to avoid construction joints, the most convenient arrangement of forms and reenforcement should be decided on before construction is started. Forms should be oiled, to facilitate their removal.

Delay in setting the forms for the upper part of the tank can be minimized if the forms are arranged as panels that can be quickly assembled and the reenforcement, if not too heavy, is bent and wired together ready for placing. If the pouring of the concrete cannot

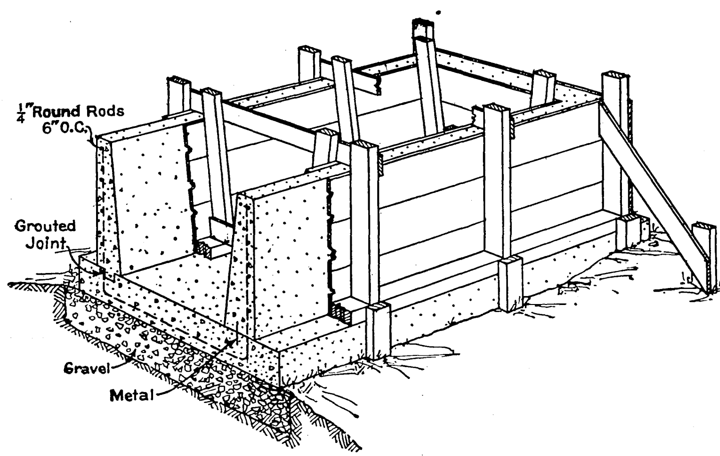


FIGURE 34.—Construction of a rectangular trough on a sub-base. Water-tight joints made with a 6-inch strip of galvanized metal or grouted tongue and groove.

be completed in one day, the bottom can be poured and allowed to harden before the walls are placed, provided due precaution is taken to obtain a watertight joint between the floor and walls (fig. 34).

A convenient arrangement of forms for a trough requiring no footings but with a sub-base is illustrated in figure 34; the arrangement of forms where footings are required is shown in figure 35. In the latter case the footing trenches should be dug and the outside form set in place; the trenches should be filled with concrete and 2 inches of the floor put in place; after the steel has been set the rest of the floor should be poured; the inside form may then be set and the walls completed. Forms for round troughs are somewhat more difficult to make.

### SMALL FEEDING TROUGHS

Troughs similar to those shown in figure 36 are convenient for feeding and watering hogs or other small animals. The dimensions may be varied to suit special conditions. If it is to be precast, a trough should not be made more than 2½ feet wide, 5 feet long, and 18 inches high. If cast in place, a trough may be 10 feet long and

as wide as desired, but should not be over 18 inches high. Reinforcement is desirable to insure against cracks and breakage.

Figure 36, *A*, shows a form for casting a trough upside down, using an earth core. The core is built approximately to shape of plastic earth; the bottomless box is then secured in place with stakes, and the core is worked to exact shape with the template *B*, the form

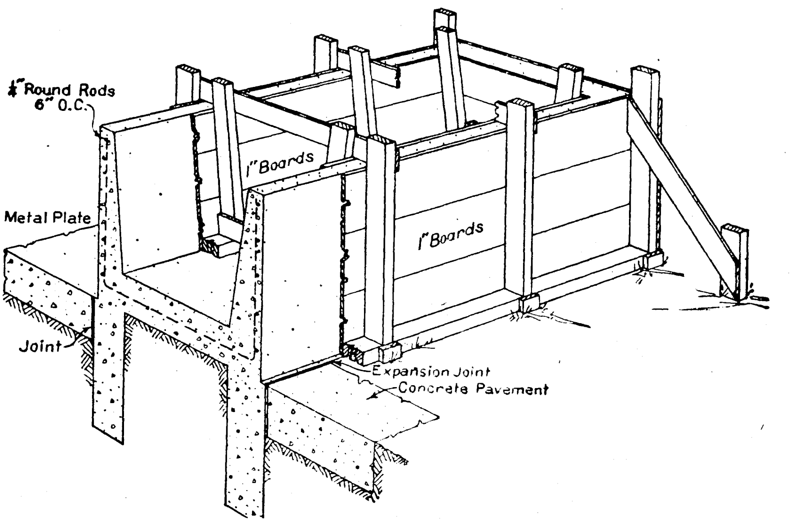


FIGURE 35.—Construction of rectangular trough directly on the ground. The pavement is laid after the trough is completed.

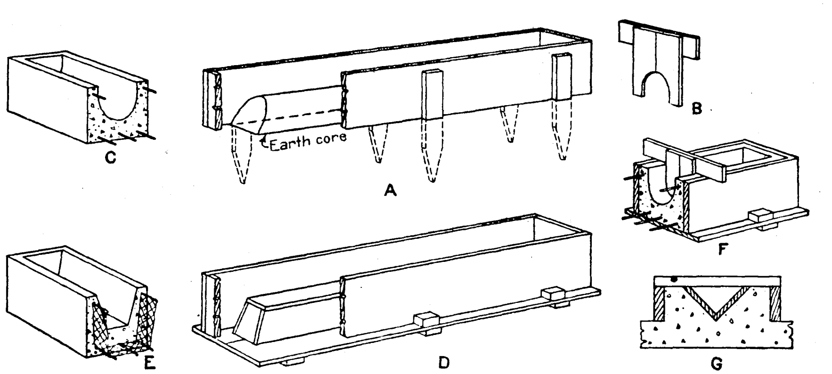


FIGURE 36.—Construction of feeding troughs, reinforced with ¼-inch rods or lightweight woven wire: *A*, Form for casting trough upside down; *B*, template; *C*, section of completed trough; *D*, wooden core and pallet; *E*, section of completed trough; *F*, form for casting trough upright; *G*, form for casting trough directly on concrete floor.

being used as a guide. *C* is a section of the completed trough. The use of a wooden core and a pallet on which the trough may be cast and carried to the place where it is to be used, is illustrated in *D*, and *E* is a section of the finished work. A third method is shown at *F*. After the forms for the trough are set, the concrete is poured, worked into place with a trowel, and shaped with a template. A mortar topping or surface coat is then placed and troweled to a

smooth surface. Sometimes the sides and ends of a trough are cast directly on a concrete floor which forms the bottom of the trough, as in *G;* in such case the sides should be built before the concrete floor hardens, or they may be poured at the time the concrete of the floor is placed.

The treatments recommended for milk-house floors, page 35, will afford some protection against deterioration due to the action of slops fed in the trough.

## PRECAST UNITS

### FENCE POSTS

Concrete line posts are made in a variety of shapes and are usually 7 to 8 feet long. Figure 37 illustrates a home-made form for a tapered post 4 by 3 inches at the top and 4 by 5 inches at the bottom. Commercial metal forms are economical where a large

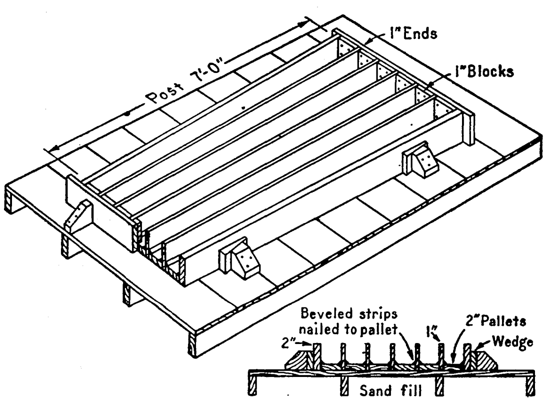


FIGURE 37.—Form for making concrete posts.

number of posts is to be made, and generally produce posts of better appearance than do wooden forms. Each post should be reinforced with four ¼-inch rods accurately located, one in each corner, so as to have at least a ¾-inch covering of concrete. Square rods are better than round rods, which are more often used. The rods should be 3 inches longer than the post to permit bending hooks on the ends to prevent the reinforcement slipping when stressed. A good plan sometimes followed is to bend long rods into hairpins, with hooks on the ends and use two hairpins instead of four separate rods. As a post can be seriously weakened by misplaced reinforcement, it is advisable to use spacers made of baling wire to hold the rods in position.

The concrete should be mixed in the proportions of 1:2:2, and it should be just sufficiently plastic to place around the steel.

In placing the concrete, about 1 inch should be put on the bottom of the form, then two rods, or one hairpin, fastened together with five wire spacers, should be pressed into the concrete so as to be three-fourths of an inch from the bottom and sides. Concrete should be placed on these to three-fourths fill the form, then two more rods with

spacers should be placed similarly to the first pair, and the form filled. As the forms are filled they should be jarred or tapped to compact the concrete, and the aggregate should be pushed back from the sides by spading, but care must be taken not to displace the reinforcement. The exposed surface can be smoothed with a float. Because posts of small cross section are easily broken when new, care must be exercised to properly cure them and guard against jolts that may cause damage. The posts should be left in the forms until the concrete hardens—24 hours in summer—after which they can be carried on the pallet to the curing site. A bed of sand or soft moist earth is desirable, as the posts can be turned and slid carefully from the pallet and then covered with moist sand where they should be left 28 days protected from heat and drying winds. Posts should not be set in the fence row until 28 days after casting, and it is better to let them cure 2 to 3 months before using.

A post of the cross section mentioned above weighs about 109 pounds and has a volume of three-fourths of a cubic foot. Approximately 36 posts can be made from 1 cubic yard of concrete. One man should be able to make 5 posts an hour. Reinforcement is sold by the pound, and 6 feet of ¼-inch round steel or 4.71 feet of ¼-inch square steel weigh about 1 pound.

The cost of making posts can be estimated by substituting local prices for the prices used in the following example.

*Computation of cost of 100 posts of type described*

[75 cubic feet=2¾ cubic yards of 1 : 2 : 2 concrete (table 2)]

| | |
|---|---|
| 2¾ by 8.2=23.5 sacks cement at 90 cents | $21.15 |
| 2¾ by 0.6=1.65 cubic yards sand at $1.50 | 2.47 |
| 2¾ by 0.6=1.65 cubic yards gravel at $2 | 3.30 |
| 2,900 linear feet ¼-inch rods=484 pounds at 5 cents | 24.20 |
| 20 man-hours (5 posts per hour) at 70 cents | 14.00 |
| Form (approximate) | 40.00 |
| Total | 105.12 |

The cost per post at the prices shown will be approximately $1 where cash must be paid and only 100 posts are to be made. If gravel, sand, and labor are supplied on the farm and the forms are used without damage for 500 posts, a farmer could expect to produce posts for about one-half this price.

Corner, gate, and brace posts should be larger and are generally cast in place (fig. 38). The bottoms should be set at least 2½ to 3 feet in the ground, or below frost. A 1 : 2½ : 4 mixture may be used.

### BUILDING UNITS

Window lintels for openings not more than 5 feet wide are frequently precast to advantage. The height is usually 8 inches, to permit intermembering with block or tile of the wall; the thickness is made the same as the wall, usually 8 inches; the length is 8 inches greater than the width of the opening. Two ½-inch round rods should be placed one-half inch above the bottom for spans up to 4 feet, and three rods for 5-foot spans. The exposed face may be finished the same as the wall or be scored for stucco.

Sills also may be precast. They may be equal to or 8 inches longer than the width of the opening, depending on whether they are to be of the slip or built-in type. The top should have a slope to shed water and the under side a drip groove. Sills generally are made 4 to 6 inches thick and 2 inches wider than the thickness of the wall

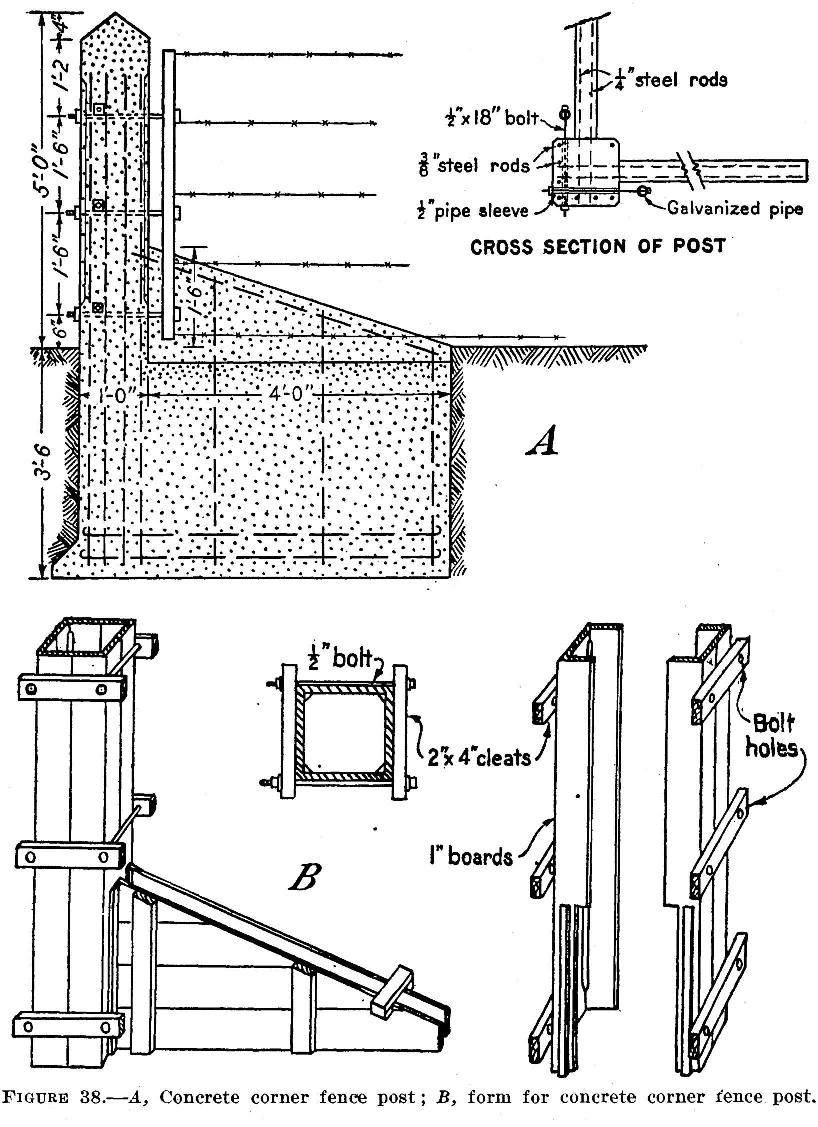


FIGURE 38.—*A*, Concrete corner fence post; *B*, form for concrete corner fence post.

(fig. 39). It is advisable to use several ¼-inch reinforcing rods 1 inch from the bottom.

Concrete planks are useful for many purposes around the farm in places where the material comes in contact with the ground, such as covers for small septic tanks, baseboards of buildings, partitions between greenhouse beds, etc. They can be made by molding slabs

1½ to 2 inches thick and 6 to 12 inches wide. If over 10 feet long they will be too heavy to handle. Wire mesh may be used for reinforcement, or ¼-inch round rods spaced one for each 3 inches of width. Ties of baling wire should be looped around the rods at intervals of 8 to 12 inches throughout the length. Such planks should be made of 1 : 2 : 3 concrete and allowed to cure thoroughly before being used. Care should be taken in handling not to break or crack them.

Other convenient building units are precast joists, tile, wall blocks, and silo staves.[6]

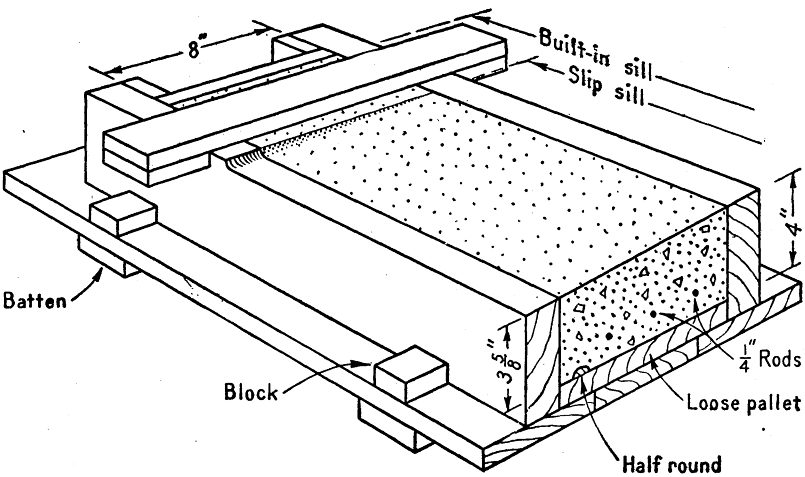


FIGURE 39.—Form for precast sills. For a slip sill, the end board, here set for a built-in sill, should be moved inward to the position indicated.

## SMALL FARM BRIDGES

Bridges for crossing irrigation ditches and small farm streams if of concrete save upkeep labor. Figure 40 shows how to build a simple

TABLE 10.—*Reinforcement and slab thickness for small concrete bridges*[1]

| Clear span | Slab thickness | Reinforcement K-rods | |
|---|---|---|---|
| | | Diameter | Spacing |
| *Feet* | *Inches* | *Inch* | *Inches* |
| 6 | 6½ | ⅝ | 8 |
| 9 | 6½ | ⅝ | 7 |
| 12 | 7 | ¾ | 8 |
| 15 | 8 | ¾ | 7 |

[1] Transverse reinforcing rods are ⅜-inch round rods placed 8 inches on centers.

bridge to accommodate a 6-ton load; table 10 indicates the reinforcement and slab thickness for four different spans. Bridges for heavier loads and greater spans and for crossing streams that are subject to wash-outs require individual consideration. Dry weather and periods of low water are the best times for construction work.

[6] Directions for making these can be obtained from cement manufacturers or from the Portland Cement Association, Chicago, Ill.

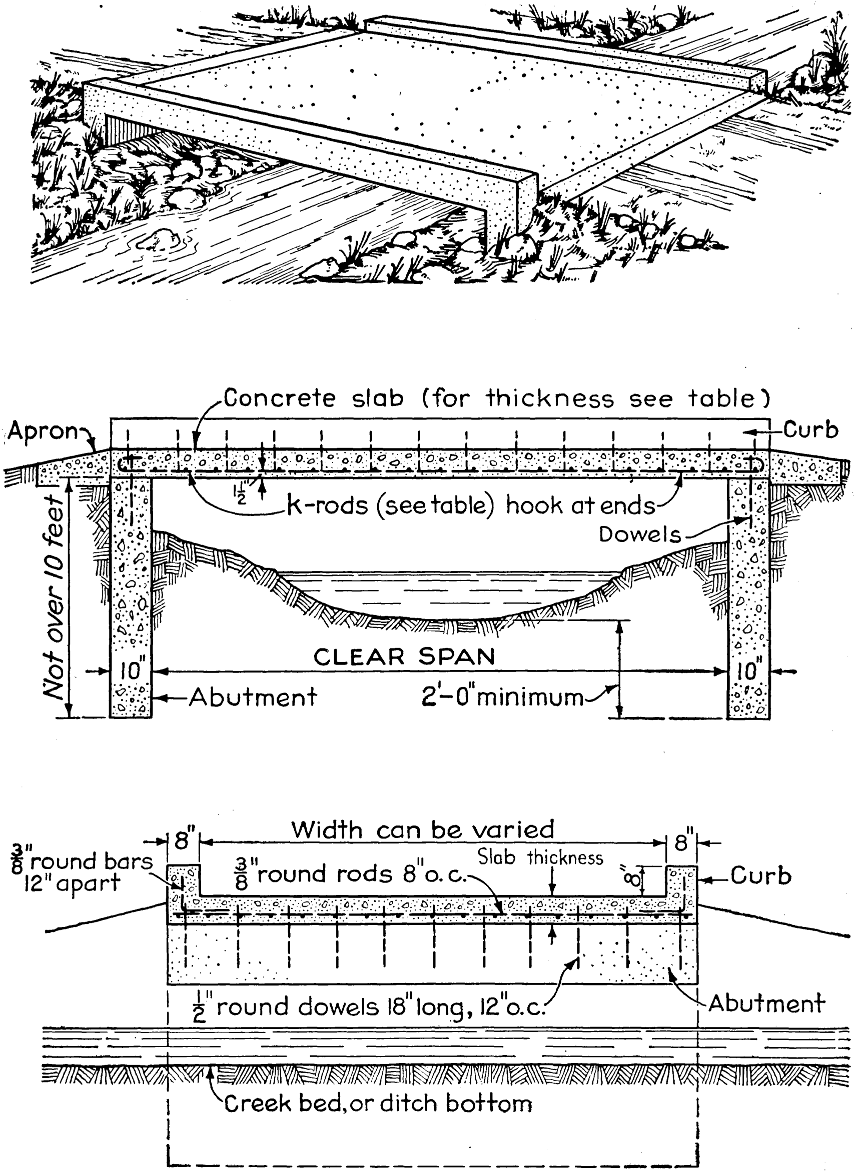


FIGURE 40.—Concrete bridge for irrigation ditches and small streams.

To prevent undermining, the abutments must extend at least 2 feet below the bed of the stream. For greater security against erosion, rock or broken concrete if available could be laid as riprap, on the embankments next to the abutments. Forms for the abutments can be built similar to those in figure 5. A platform of planks will be needed for the deck slab and it should be supported on 2- by 6-inch joists 2 feet apart. The joists should be supported by 4- by 4-inch or larger girders spaced about 4 feet on centers. Shoring needed to hold up the girders must be wedged and braced securely.

The concrete slab should be 1 : 2½ : 3½ mix and the abutments 1 : 3 : 5, as described on page 9, while the recommendations given in the fore part of this bulletin for placing reinforcement and concrete should be carefully observed.

### RETAINING WALLS

Concrete retaining walls may be built as shown in figure 41. Where the soil upon which the footing rests is not firm, special advice is needed to provide against tipping. Higher walls and walls close to the footings of heavy structures should be designed to meet the individual problem.

The footing should be below frost depth and if on sloping ground, must be built on horizontal steps.[7] Weep holes should be provided clear through the walls to drain water from back of the wall. These should be 4 inches in diameter, 6 to 8 feet apart, and about 6 inches above the lower surface grade; 4-inch drain tile are often used.

The concrete can be 1:3:5 mix. Where field stones are plentiful about a half to two-thirds the quantity of concrete can be saved by embedding the stones in the concrete. The stones should be sound, free of earth, dampened before being placed, and not larger than half the thickness of the wall section where embedded. Stones should have at least 2 inches of concrete between adjacent pieces and be kept back from the face of the wall.

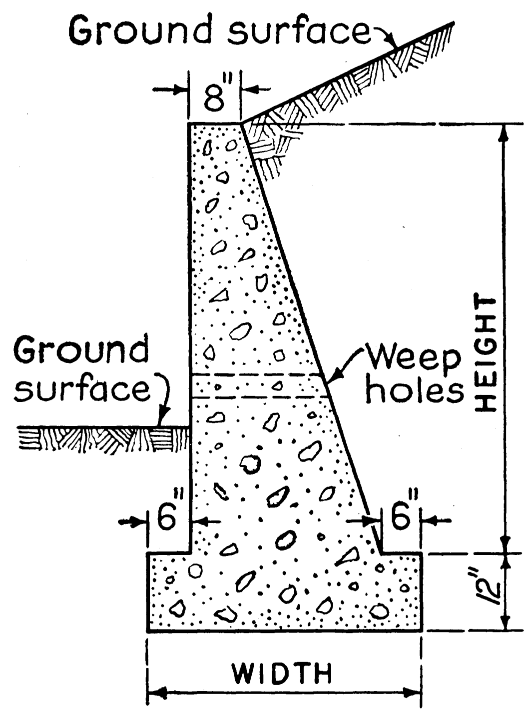


FIGURE 41.—Gravity-type retaining wall.

Sometimes walls are built of reclaimed concrete road slabs broken into pieces convenient to handle and laid with mortar joints.

[7] See fig. 4, Farmers' Bulletin 1869, Foundations for Farm Buildings.

The width of the footing should vary in proportion to the wall height as follows:

| *Wall height (feet)* | *Width of footing (feet)* |
|---|---|
| 3 | 2½ |
| 4 | 3 |
| 6 | 4 |
| 8 | 5½ |

Backfill should not be placed until the concrete has thoroughly hardened, which usually requires 27 days.

### PORCH FLOORS

Porch floors may be laid on an earth fill or supported above the ground. When placed at about ground level the slab may be built according to directions on page 35 for building feeding floors. The earth should be well settled, a porous subbase should be provided, and aprons (fig. 15) should be built under the edges of the slab. The slab should slope about one-fourth inch per foot to drain off water. Sometimes ⅜-inch round rods are set 1 inch from the bottom of the slab, 12 inches on centers both ways.

Supports are needed where the slab is elevated or is on a fill greater than 12 inches thick. While reinforced girders resting on piers could be used, two walls built of 8-inch concrete blocks eliminate the need for forms and girder reinforcement and therefore are easier to build when small porches are added to existing structures. Walls are not needed under the ends of the slab.

Figure 42 shows details of construction and table 11 the quantity of reinforcement and the thickness of the slab needed for porches 4 to 10 feet wide. Concrete should be 1 : 2½ : 3½ mix.

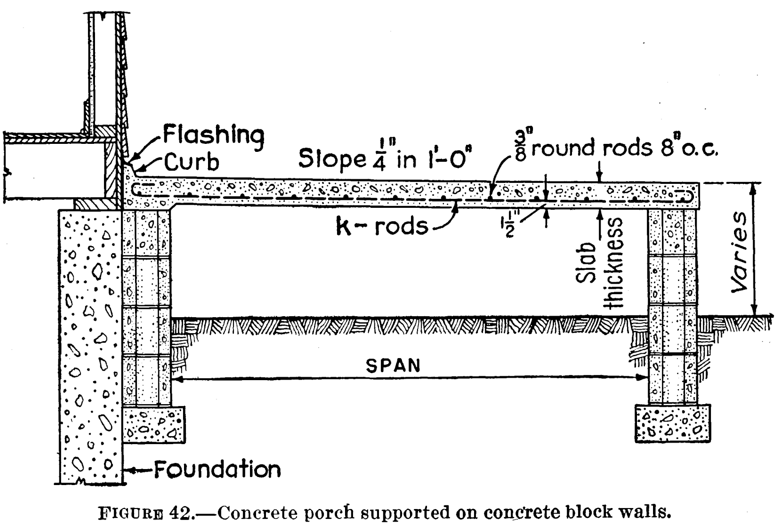


FIGURE 42.—Concrete porch supported on concrete block walls.

TABLE 11.—*Reinforcement and slab thickness for supported porch floors*[1]

| Clear span | Slab thickness | Reinforcement K-rods | |
|---|---|---|---|
| | | Diameter | Spacing |
| *Feet* | *Inches* | *Inch* | *Inches* |
| 4 | 5 | 3/8 | 7½ |
| 6 | 5 | 3/8 | 6 |
| 8 | 5½ | ½ | 9½ |
| 10 | 6 | ½ | 8 |

[1] Transverse reinforcing rods are 3/8-inch round rods 8 inches on centers.

## REPAIRS TO CONCRETE STRUCTURES

### BASEMENT WALLS

Frequently basement walls, especially if built of masonry units, do not prove watertight. In many instances the wall would have been satisfactory if due precaution had been taken at the time of building to provide proper drainage of the site. Even a wall of good monolithic concrete should not be relied on where it is known that the ground-water level is high and the site poorly drained. Drain tile should be installed around the footing of the foundation and sloped to a suitable outlet. The cost of such drains installed at the time of building is relatively insignificant as compared with the annoyance, structural damage, and probable insanitation that may result from damp structures.

### FLOORS

Repairs to plain concrete floors usually consist of replacing broken parts, patching holes or worn spots, regrading shallow sinks caused by settlement, cutting out humps caused by expansion, resurfacing to improve foothold, and changing slopes to shed water. Cracks of whatever origin are difficult to repair. If of appreciable extent or too evident, it is advisable to remove the surface for a depth of 1 inch over the whole area affected and replace the topping as described below for patching holes. Where a thin coat of only 1 or 2 inches thickness is necessary, it should be composed of 1 : 2 mortar. If a greater thickness is required, the mixture should be 1 : 2 : 3, the coarse aggregate being of a size equal to about one-third the depth of the depression but not in excess of 1 inch.

In patching holes or regrading shallow sinks, the old concrete should be trimmed away until sound material is reached, or at least deep enough to allow for 1 inch of new material. The edges of the adjacent good concrete should be kept nearly vertical. The old concrete should be soaked with water, the excess water removed, and the concrete given a coat of grout. While this is still moist, the new concrete should be placed and rammed. After it has stood for from 5 to 20 minutes, the patch should be rammed again, to minimize later shrinkage. The surface should be worked with a wooden float so as to conform to the surrounding concrete, special care being taken to produce a good finish at the edges of the patch. The new concrete should be covered and kept moist for several days. A floor that has worn smooth can be roughened by picking the surface with a sharp tool.

Concrete that has been cut to permit work involving the removal of earth beneath it should not be replaced until the backfill has been thoroughly settled and rammed.

### CRACKS

Sometimes small cracks occur in concrete walls, tanks, etc., which do not necessarily affect the strength of the structure but are unsightly. These are difficult to repair on account of being so narrow. If the crack is widened by cutting away the concrete to form a 1- or 2-inch groove, it can be repaired by filling with cement mortar. Technical advice should be sought before attempting to repair cracks in beams or columns supporting loads. (Regarding cracks in floors, see preceding section.)

### CLEANING

Concrete walls stained by dirt and weather can be cleaned by being scrubbed with a stiff fiber brush and water. If stains are persistent, sometimes a solution of 1 part of hydrochloric acid in 3 to 10 parts of water is effective. The walls should be dampened before the solution is applied, and when it stops foaming they should be washed with copious applications of water. In many cities there are firms that specialize in cleaning buildings and are equipped to use live steam and sand blasting.

Efflorescence is a whitish deposit that sometimes occurs on masonry. It may be removed by the acid treatment just described. If the surface of the concrete is colored for ornamentation, it is best not to leave the acid on the wall longer than 4 minutes because it may etch the concrete. A second application can be made if necessary. Efflorescence can be removed also with a solution of equal parts of paraffin and benzine rubbed into the surface of the dry concrete.

The appearance of concrete after cleaning can be freshened by a brush coat of grout made with white cement, or by applying a commercial cold-water paint having a cement base. Cement grout adheres better when applied to a damp wall. Whitewash [8] is frequently used on the outside of structures and is especially esteemed because of its light-reflecting characteristics. It is not so permanent, however, as the cement washes and should not be used on damp inside walls. It is very desirable for the outside of farm buildings that become quickly soiled, because it is low in cost and easy to apply.

The following white coat adheres well to masonry walls exposed to dampness and outside conditions.

Mix 1 sack white portland cement and 25 pounds of hydrated lime. For every 100 pounds of this mixture use 2 pounds of calcium chloride dissolved in 1 quart of water and add to the lime-cement mixture; then add enough water to make a good brush paste and apply with a wire brush. Wet wall prior to coating and apply two coats 24 hours apart. Mix only the quantity of wash that can be applied within half an hour.

[8] See whitewash formula in Farmers' Bulletin 1452, Painting on the Farm.

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